PARTICULATE POLLUTION IN SOME FIBRE FACTORIES IN KANPUR

A Thesis Submitted
In Partial Fulfilment of the Requirements
for the Degree of

MASTER OF TECHNOLOGY

By

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to the

DEPARTMENT OF CIVIL ENGINEERING

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JULY 1975

.... to Valsala,

Saya and Sniya.

CERTIFICATE

Certified that the work presented in this Thesis entitled 'Particulate Pollution in Some Fibre Factories in Kanpur' by Shri V.A. Sudhakaran has been carried out under my supervision and it has not been submitted elsewhere for a degree.

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SYNOPSIS

This thesis presents the details of studies carried out in three fibre factories - one each of a jute, cotton and woollen mills - in Kanpur for ascertaining the particulate pollution conditions in their working environments, in general. It also gives results of detailed studies carried out in the jute mill to determine the health effect of particulate pollution on workers and to evaluate the adequacy of existing ventilation system in reducing the pollution. The results indicates that the pollution levels in the preparing sections of all fibre factories are higher than permissible limit, during all seasons of the year. A small percent of workers in the preparing sections of the

jute mill seems to show symptoms of Byssinosis. The results also indicates that existing ventilation is inadequate and natural ventilation alone cannot be depended upon for reducing particulate pollution. Modifications are suggested for improving the existing ventilation system. An outline of design considerations for a ventilation system for new jute mills is also given.

CHAPTER I

INTRODUCTION

Man, today, is fully aware of the adversities of pollution around him. Industrial workers are often exposed to a much more severely polluted environment on the shop floo than would ever be experienced by the community in general. The capability of man to adapt to adverse conditions is well known. But the pollution conditions present in many industries are so severe that his tolerance limits are always exceeded and hence the problem. Today's factory worker is becoming more and more aware of these facts and is demanding a healthier and more comfortable environment to work in. A group of contented workers is an asset for any industry and for the country as industries are the buildings blocks of a nation's economy. Industrial hygienists have a great task of identifying the vast multitude of pollution problems and finding methods for their solution.

1.1 HISTORY

Awareness of man towards occupational diseases dates back to the times of Hippocrates who lived in the fourth century B.C. and was the first to record the adverse effects

of lead exposure upon miners and metallurgists. But the problem was not severe till the advent of Industrial Revolution. In the initial stages of the revolution, health and comfort of workers were not matters of concern for industrialists. By the beginning of the 19th century, labour legislations came into force (Patty 1958) and this paved the way for developments in the field of industrial hygiene. From then onwards, the progress made in this field is very encouraging. Today, industrial hygienists are capable of anticipating and preventing most hazardous situations before serious injuries are resulted.

1.2 PROGRESS OF INDUSTRIAL HYGIENE IN FOREIGN COUNTRIES

Industrially developed countries like the U.S.A., England, Russia, Germany and Japan have made extensive strides in the field of Industrial hygiene. Laws have been promulgated requiring industries to remove dust and injurious gases from the working area and to give compensation to workers for accidents and infirmity resultedfrom working in dangerous trades. In the U.S.A. many voluntary and social organizations have also done good service in collecting data and suggesting control measures. Some Educational Institutions have started giving specialized instructions in this field from 1940 onwards. In England medical phases

of industrial hygiene have received more attention than technical and engineering phases of evaluation and control In Russia special attention is given to questions involving better labour conditions. In Germany numerous regulations are aimed toward medical examination and mechanical safeguards. The regulations are enforced by a host of factory inspectors. Japan has established an Industrial Hygiene association. There is ample evidence of growing interest in industrial hygiene in nearly all countries.

1.3 CONDITIONS IN INDIA

The hygienic conditions in Indian industries are very poor and little is done in improving them compared to the big advancements made by developed countries in this field. Many reasons may be attributed for this unfortunate situation and some are given below :

1) lack of information regarding pollution conditions in various industries,
2) the enormous cost of control measures,
3) justified reluctance on the part of industrialists to invest huge amounts on control measures which give no return in terms of money.
4) unawareness of the workers of the potential dangers of pollution,

5) lack of effective legislation for implementing control measures (The penalties for not abiding the law are gene meagre and industrialists may be happy in paying the penalty rather than investing on costly control measures); and

6) the unscientific way of implementing existing legislations. (At present pollution conditions inside factori are assessed on the basis of reports from factory inspectors who seldom do their job sincerely).

1.4 POLLUTION CONDITIONS IN FIBRE INDUSTRIES

Fibre factories, mainly, have particulate pollution problems. During the preparing and finishing processes of natural fibres many particulates like dust, fibre and fumes will be escaping into the working environment of the factorie The nature and concentration of these particulates will depend on the type and grade of the raw materials, type of processing, effectiveness of control measures provided, if any, and the general ventilation conditions in the factory rooms. Exposure of workers to the pollutants is likely to be injurious to their health.

1.5 EFFECT OF PARTICULATE POLLUTION ON WORKERS

Particulate pollution in fibre factories have the following direct and indirect effects on the workers.

1.5.1 Direct effects :

Particulates of sizes less than 10 microns will go into the lungs of workers during respiration. A large portion of the fine particulates will be deposited in the lungs causing pulmonary dust diseases like silicosis, fibrosis, byssinosis, etc.

1.5.2 Indirect effect :

Indirectly particulates act as carriers of pathogenic organisms and toxic and irritant gases. Thus common cold, influnza, tubaculosis, etc, can be communicated through dust carrying these causative agents. Toxic gases which would have been removed in the upper parts of the respiratory tract are carried deeper into the respiratory system by dusts which sorb and retain the gases.

1.6 FIBRE INDUSTRY IN INDIA

In India, we have all types of fibre factories, synthetic and natural. Particulate pollution in synthetic fibre factories are relatively much less compared to that in natural fibre factories due to the well controlled atmosphere needed and maintained even if for entirely different reasons.

Cotton industry is the largest single industry in India. In 1972, cotton textile industry consisted of 674 mills

with a total installed capacity of 182 lakh spindles and 2.08 lakh looms. The number of workers employed in these mills stood at 9.57 lakhs (Publications Division 1974). The major areas of cotton industry are Ahmedabad and Bombay. Kanpur is the largest centre of cotton textiles industry in Northern India and has 14 cotton mills.

As the biggest foreign exchange earner, jute industry occupies an important position in the country's economy. The export earnings from jute materials was Rs.263.29 crores in 1971-72. (Publications Division 1974). The jute industry employs 240,000 persons - 9 percent of factory labour in India (Kothari and Sons 1972). There are 64 jute mills in India of which 54 are located in West Bengal (Sham Lal ed. 1972). The amount of jute processed comes around 70 lakh bales per year. Kanpur also has a few jute mills.

There are 102 woollen mills in India and majority of them (40) are situated in Punjab. One of the largest, the 'Lal Imli' is however located in Kanpur.

The particulate pollution conditions in most of these factories are severe as there are but few control measures to reduce pollution. From the data given above it is clear that a large number of workers are exposed to the adverse effects of particulate pollution in fibre industries. The

resulting loss to the nation in terms of medical expenses and man-hours is bound to be quite significant.

1.7 NEED FOR PRESENT STUDY

The present study was undertaken with the specific purpose of ascertaining the particulate pollution conditions in some fibre factories of Kanpur and its effect on workers. Attempt was also made to determine the influence of ventilation on particulate concentrations and transport inside the factory rooms. It is expected that the results of the study may serve as a basis for the design of improved ventilation systems for fibre factories with a view of reducing particulate pollution hazards to the health of workers.

CHAPTER II

LITERATURE REVIEW

Occupational diseases and their causes were topics of intense study during the last many decades. Health conditions of workers in cotton mills were quite deplorable till people recognised the actual causes. Investigations by Prausnitz (1932) showed that the inflamatory irritation of nasal pharynx and bronchi among workers of cotton industry was caused by the high dust concentrations. Other investigators like Roach and Schilling (1960), Mekky et al (1967) and Popa et al (1969) have studied the health conditions of workers in textile mills and found that their respiratory functions were adversely affected by the dust inhaled by them. The influence of inhaled dust on respiratory diseases was so pronounced that terms like 'pulmonary dust disease', 'pneumoconiosis' (a lung containing dust), etc have been added to the medical terminology.

2.1 PARTICULATES AND THEIR EFFECT ON HEALTH

Particulate is a term used to represent a large number of contaminants. According to Patty (1958), particulate matter includes aerosol, dust, fog, fume, mist, smog and smoke. In the present study the term particulate is used

Fig(5) CALIBRATION CURVE

of dust.

The entry of dust into the respiratory system and its possible retention there depends on the particle size. LaBelle (1955) records that only 20 percent of particles of 5 size will penetrate the nasopharynx where as there will be 100% penetration by 1 μ size particles. Brown et al (1960) explain the differential settling of dust particles at various levels of the respiratory tract. The particle size is also important from the point of view of particulate transport in the working environment. According to Hemeon (1963) fine particles of size less than 20 μ will move with the room air. So the escape of such particles into the air from various industrial operations will find its way into the respiratory system.

Surface area of dust is important as the same decides the amount of toxic gases sorbed by the dust. Synergic effect of aerosols causing changes in toxicity to rodents is reported by LaBelle (1955). Inert dust may become additionally harmful when some toxic gases also are present in the atmosphere. Fine particles will have a very large surface area. If a cube of a mineral 1 cm. side were ground to form cubes of 1 μ size, it will result in 10^{12} particles with a total surface area of 6 sq. meters as compared with 6 sq.cm. for the original cube.

The settling rate of particulates are important in designing control measures for dust pollution. Chemical nature of the dust decease which the particulate will cause. For example the presence of free silica in the environment in sufficient concentrations will lead to silicosis.

2.2 FATE OF DUST ENTERING THE RESPIRATORY SYSTEM

The human respiratory system is meant for supplying oxygen into the blood stream and removing carbon dioxide from it, the exchange sites being thin walls of alveoli situated deep in the lungs. Dust entering the lung with the air is a foreign matter and will do harm to the normal functioning of lungs.

During inspiration air enters the nasal openings, passes through the pharynx, larynx, trachea, bronchi and bronchioles, into the air sac or alveoli (Hamlin 1944). Particles of size more than 15 to 25 microns will be caught in the nasal passage or at the back of the throat. Particles in size range of 5 - 15 microns impinge and get deposited on the moist walls of the respiratory passage (Altshuler 1957) In the alveoli, the air is moving very slowly and finer particles settle and come in contact with the moist alveolar wall.

will decide the type of pulmonary dust

Particles caught before reaching the alveoli are continually swept toward the mouth by the ciliated epithelium. Particles caught in the alveoli may be absorbed though the alveolar wall or may be engulfed in phagocyte cells and be carried into the blood capillaries, ∠tracheobronchal lymph nodes. It is here that fibrosis of healthy lining tissues starts following quartz-dust inhalation. Excessive inhalation of dust causes serious pulmonary disease generally named Pneumo-coniosis. Silicosis, asbestosis, anthracosis and byssinosis are few forms of pneumo coniosis, the names being derived from the type of dust deposited.

2.3 PNEUMOCONIOSIS

2.3.1 Byssinosis

This is a chronic respiratory disease of cotton, flax and hemp workers, characterised by chest tightness and breathlessness at work after the weakend break or other absence (Schilling 1971). Epidemiological studies revealed that more than 40 percent of workers may be affected with less dust control. Recent evidence confirm that the disease in caused by some brancho-constricting agent contained in the leaves of cotton plant, but not in the fibres or seeds (International Labour Organisation 1971).

∠ or enter the lymphatics and be concentrated at the

2.3.2 Silicosis :

This is caused by inhalation of air containing free silica (Drinker and Hatch 1954). Workers in mines or rock crushing units, where SiO_2 content may be high in the air, are more susceptible for this disease. But in fibre factories also room air may contain silica released from the raw material. This may be more probable in woollen mill as raw wool will contains a good amount of silica. Cotton and jute also may contain silica depending on where they grow and how clean the raw materials reaching the factory are.

2.3.3 Fibrosis :

The pathologic changes caused by fibrous particulates are not like silicosis. The fibres group about the neck of an alveolus and stimulate the formation of a diffuse fibrosis (Drinker and Hatch 1954). As fibrosis increases, the reduction of lung area causes serious dyspnea.

2.4 OTHER HAZARDS OF DUST

Dust can be hazardous to man in an indirect manner too as carriers of pathogenic organisms and toxic gases.

2.4.1 Dust as carriers of pathogenic organisms :

Microorganisms in the atmosphere are usually attached to aerosols. Caminita et al (1943) have found Gram-

negative microorganisms occuring in large numbers in low-grade cotton. The organism was responsible for acute illness which closely resembled 'mill fever' reported among cotton mill operators.

2.4.2 Dust explosion :

According to the Report of Important Dust Explosion (1957) many industries including cotton mills are susceptible for dust explosions. The explosion takes place when the concentration of certain particulates exceeds the Lower Explosion Limit (LEL).

2.5 CONTROL OF HEALTH HAZARDS DUE TO DUST

2.5.1 Pneumoconiosis

There are two ways of controlling occupational diseases. viz. medical control and Engineering Control (Sander 1958). In medical control the workers exposed to dangerous concentrations of dust will be given annual medical examination which includes X-ray of the chest. The patient may be advised to leave or change the job depending on his pathological condition.

In engineering control the basic cause in the pollution condition will be reduced to tolerable limits. This has some advantage over the medical control as 'prevention is, always, better than curve'.

There are two standards for fixing the tolerance levels for different pollutants. As per the hygienic standard only such concentrations of pollutants will be permitted which do not directly or indirectly exert harmful or unpleasant effects on man. According to the sanitary standard the tolerance level is fixed considering the economical attainability and local conditions.

For example the permissible level of dust concentrations in industries is fixed by the American Conference of Governmental Industrial Hygienists based on the epidemiological survey of 458 cotton mill workers in which dust concentrations were also measured. The results were plotted on a graph as shown in Fig. 2.1. At a concentration of 4 mg/m^3 more than 50 percent of workers had symptoms of Byssinosis. But there is a point in the graph at 1 mg/m^3 when the percent incidence was negligible. So this concentration was chosen as the permissible limit. (International Labour Organisation 1971).

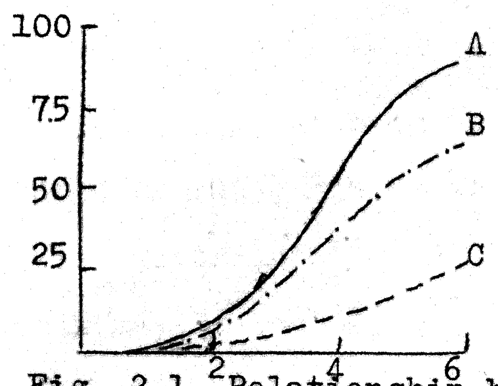


Fig. 2.1 Relationship betwe[en] Prevalence of byssinosis and dust concentration. A, all grades, B, grades 1 and 2, C, grade 2.

2.6 ENGINEERING CONTROL OF PARTICULATE POLLUTION

There are different methods of engineering control for reducing particulate pollution. Enclosed

processes, exhaust ventilation, process modifications, etc are a few engineering techniques used to ensure safe concentrations of dust in the air breathed by workmen (Sander 1958). Personal protectives like respirators will afford individual protection under certain circumstances.

Enclosing the sources of potential dangers will prevent the dispersion of pollutants into the working environment thus protecting the worker. Exhaust ventilation removes contaminated air continuously so that their pollutant concentration never goes above permissible limits. Hewitt (1973) gives a method for the effective containment of air-borne contaminants by controlling the air flow pattern. This is a very useful method and will have wide applications in particulate pollution control. Works of Tuve (1944), Hama (1973), Dean (1974) etc give methods for the design of ventilation systems to reduce particulate pollution in industries.

Process modifications are methods like wetting to reduce the escape of particulates. (Bamford 1955) has determined the optimum moisture content which gives least dust raising in a foundary. Similar methods may be possible, in fibre industry also.

Particulate pollution control is well within the capacity of engineers. The fine particulates of hygienic

significance can easily be removed or prevented from reaching the breathing zone of workers by controlling the air flow patterns and providing sufficient flow rates. The methods presently available are quite adequate for this purpose. In this connection it may be pointed out that ultrafine particles below 0.35 μ size, which are difficult to be removed from air streams, will not be deposited in the human lungs (Altshuler 1957). So an engineering control measure to eliminate all particulates of hygienic significance from the working environments of fibre factories will not be an 'utopian' dream but a practical feasibility.

CHAPTER III

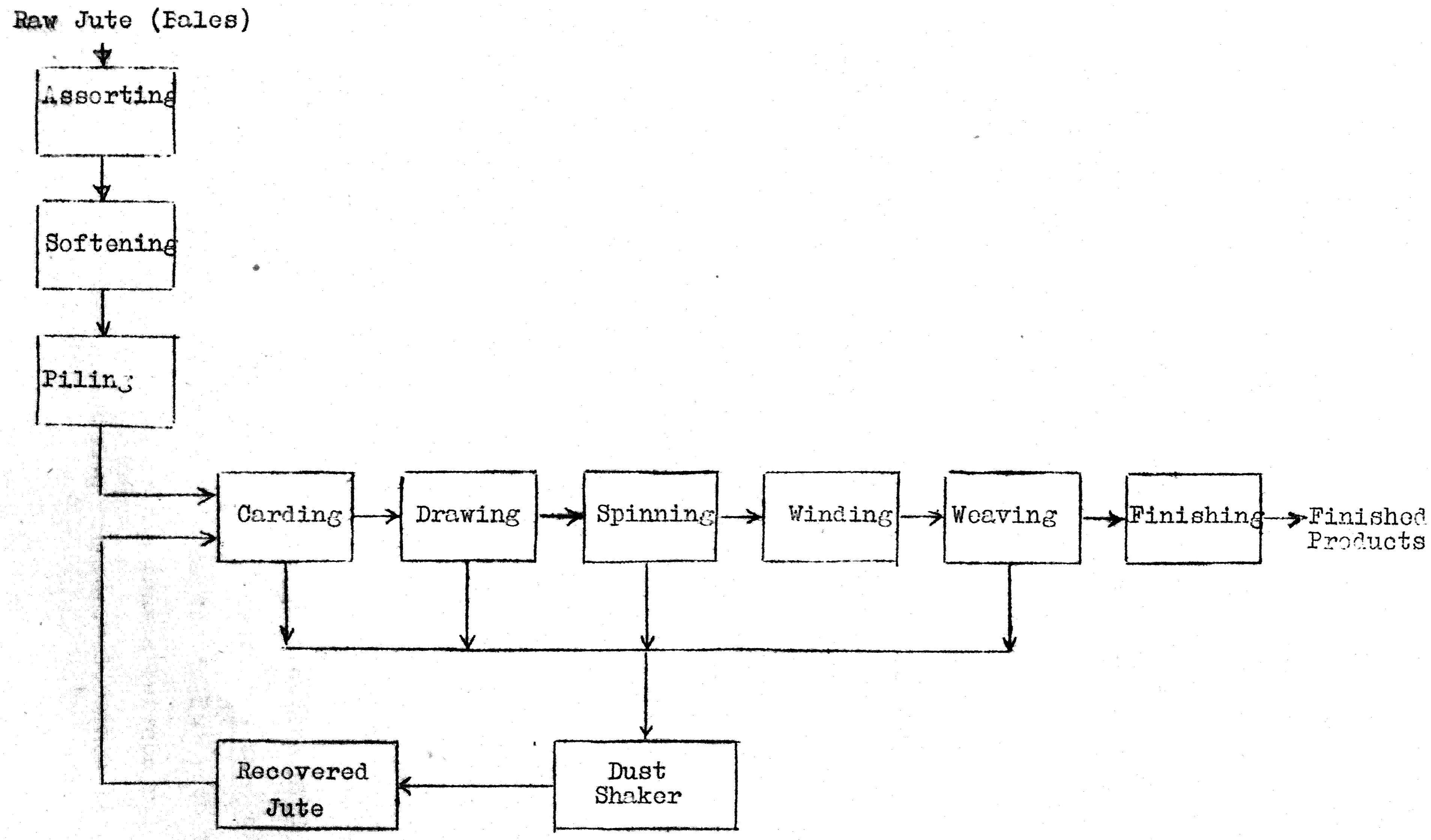
PROCESS DETAILS AND GENERAL POLLUTIONAL SITUATIONS IN FIBRE INDUSTRY IN KANPUR

Fibre factories may be broadly classified into two catagories - natural and synthetic. For synthetic factories, complete or partial air conditioning is a process requirement. So particulate pollution - a problem facing most fibre factories - is nearly absent in these factories. In natural fibre factories we have cotton, jute and woollen mills. Kanpur has the fortune (or misfortune) of having units of each type.

3.1 PROCESS DETAILS

3.1.1 Jute Mills :

Fig. 3.1 shows the flow- diagram of various processes in a jute mill. The raw jute is sorted out depending on their quality. An emulsion (mixture of oil and water) is sprinkled on the jute to soften it. The jute then goes to the softening section where it is sent between toothed rollers. Emulsion is supplied here also. The bigger impurities from the jute are removed in this section. The jute is then piled for a period varying from 24 hours to 5 days depending on the quality of jute, softer varieties requiring shorter periods and harder ones longer periods. The jute then goes



Dust

Fig. 3.1 Processes in a Jute Mill

to the carding section. Before feeding to the carding machines the harder portions (usually the ends) will be removed by cutting. In the carding section jute passes through three types of carding machines - breaker cards, inter cards and finisher cards - in succession. The processes are designed to break up hard tufts and to remove impurities and short fibres. (The particulate pollution is maximum in these sections.) This is achieved by passing the jute between a series of spiked cylindrical rollers. In the drawing section the sliver rolls (product of carding section) are passed through drawing frames for combing action to make the fibres parallel and to reduce the weight of fibres as per specifications. In the spinning section threads are made by high speed spinning rings. The threads are wound on rollers (beams) or cops to make 'warps' and 'wefts' respectively for weaving. The products are marketed after finishing processes like damping calendering etc.

3.1.2 Cotton Mills

The different processes in a cotton mill are given in Fig. 3.2. The raw cotton comes in the form of bales. The bales are opened and raw cotton is fed into the bale breaking machine. The cotton passes between rollers when dust and other impurities are removed. Then it passes

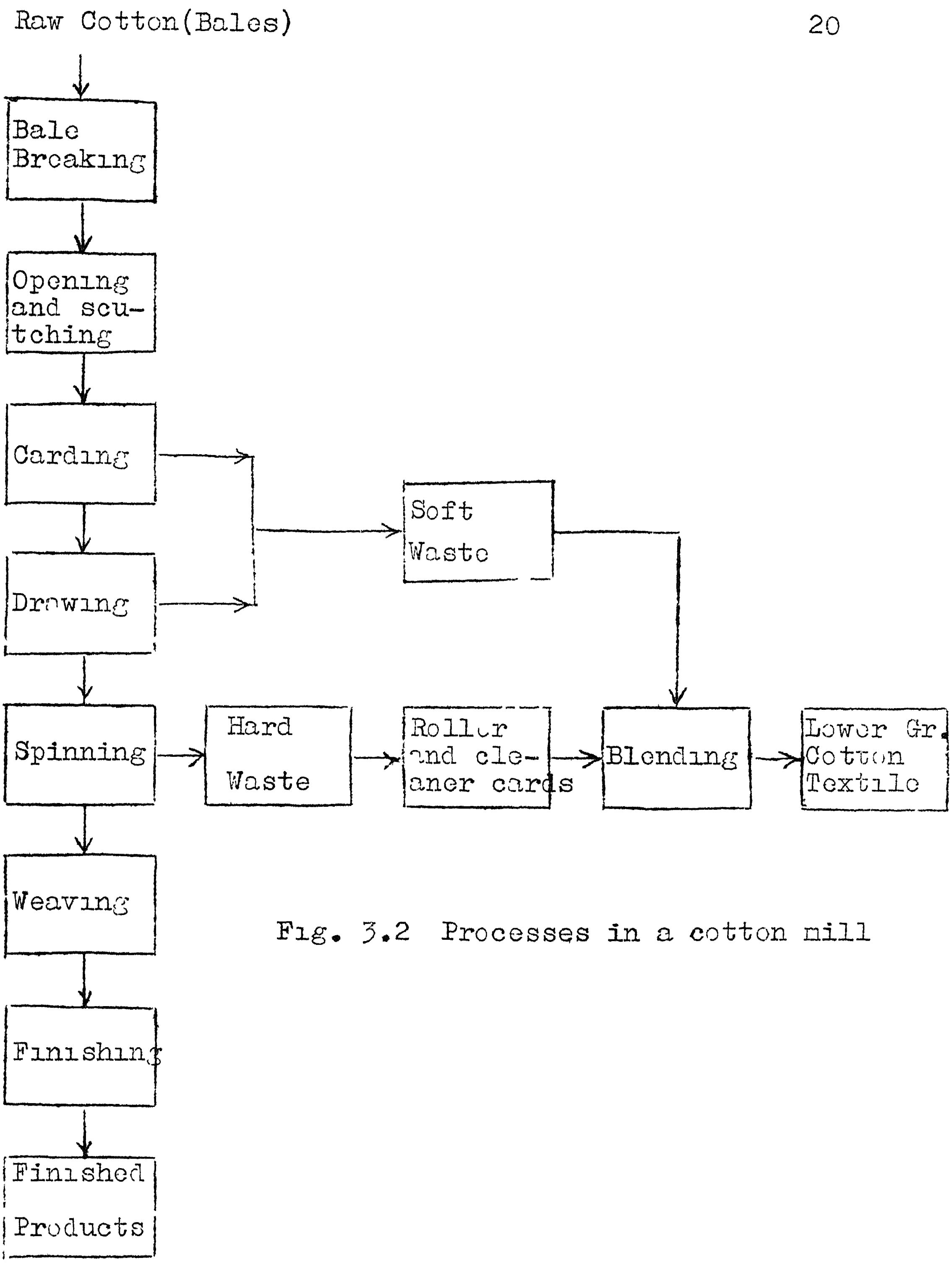


Fig. 3.2 Processes in a cotton mill

through a revolving beater where centrifugal action removes dust and impurities. Then it goes to opening and scutching machines where mixed cotton is further cleaned and opened by the combined action of revolsing beaters and air currents against a grid through which the dirt passes. The cotton emerging out, in a much bulkier form, is rolled and sent to the carding machines. Carding is designed to make the cotton fibres parallel to each other, to break up hard tufts, and to remove short fibres and impurities. For this the cotton is sent through a sieve of toothed and spiked cylindrical rollers and finally bring the fibres together in a rope like form known as sliver.

The slivers then go to the spinning section where drawing, slubbing and roving machines are used for elongating and attenuating the cotton yarn. The final step in this section is further attenuation of the yarn accompanied by simultaneous twisting. This is done by a machine called a ring frame. The yarn is now ready for weaving. The two sets of threads - warps and wefts - required for weaving are wound on long rollers and small tubes called cops respectively. The finishing operation that follows consists of a series of processes like singering, desizing, scouring, dyeing, etc.

3.1.3 Woollen Mills :

The major processes in a woollen mill are given in Fig. 3.3. The raw wool coming as bales are opened and fed to a scouring machine, where it is washed and cleaned using detergents and hot water. All dirt and grease from the wool are almost removed by this operation. The scoured wool goes to the blending section where wools of different qualities are mixed together. Fearnought, an important machine used for preparation of blends does the opening of wool preparatory to carding. Oiling of wool also is done at this stage. The wool then goes to carding section where it is sent between toothed and spiked rollers. The combing action straightens the fibres and the wool comes as threads which goes to drawing and spinning sections. In these section the threads are elongated attenuated and twisted to make fine threads. Weaving, milling and finishing of the products follow.

3.2 GENERAL POLLUTION CONDITIONS IN FIBRE FACTORIES

3.2.1 Jute Mills :

Probably, this is the most polluted of the three types of mills, especially in the preparing sections. In the assorting, softener and carding sections the particulate pollution is visibly high compared to other sections. Exhaust systems provided does not seem to function effectively. Noise levels

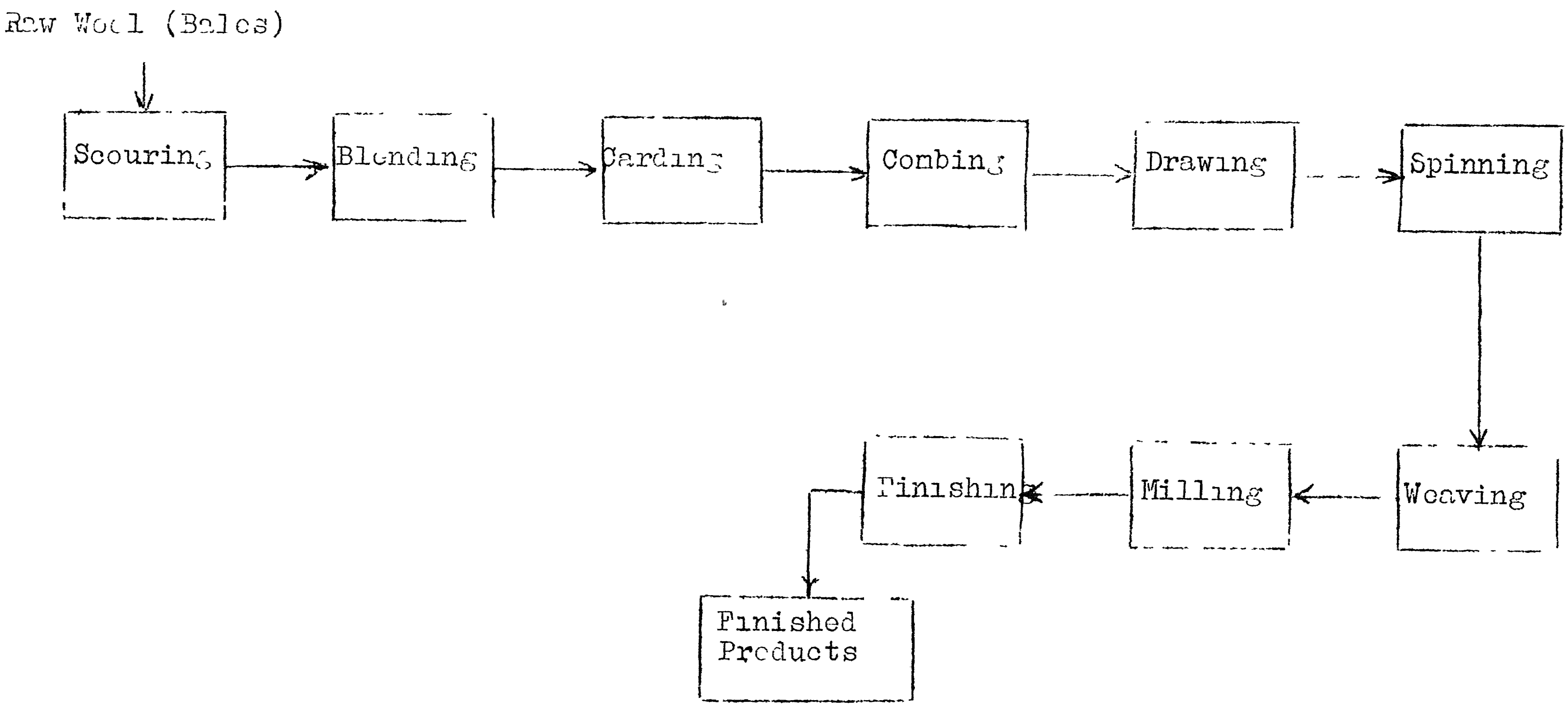


Fig. 3.3 Processes in a Woollen Mill

in the weaving section was found to be high. Most workers in the preparing sections are affected by the particulate pollution. A few workers in these sections were found to be using some cloth to cover their nostrils.

Humidifiers are used to maintain required humidity conditions. Temperature control is done only during summer when cool air is supplied into the room. But for the particulate pollution the conditions inside the factory seem to be generally, comfortable to workers. However, during hot seasons when cool air was not supplied the workers were exposed to temperature stresses. The discomfort may be caused by the high humidity. The contribution of the mill to air pollution was found to be insignificant.

3.2.2 Cotton Mills :

Pollution conditions were found to be existing in most sections of the cotton mill. The local exhaust arrangement in the preparing sections help to reduce particulate pollution to a great extend. The high relative humidity maintained in the spinning and weaving mills increases the worker discomfort. In the finishing sections like bleaching and dye houses the temperature was found to be very high. The particulates collected in the initial stages were simply released to the atmosphere. Its contribution to air pollution is more compared to that from the jute mills.

3.2.3 Woollen Mills :

Particulate pollution exists only in the scouring and old carding sections. Cool air is not supplied in any of the sections. So during summer months the heat stress on the workers is high. Contribution to air pollution is not through particulates escaping from the processes.

In general pollution condition in preparing sections of the factories are high. Workers in these sections have health problems created by particulate pollution. It seems that control of pollution is not difficult.

CHAPTER IV

OBJECTIVES AND PLAN FOR DETAILED STUDY

4.1 OBJECTIVES

The objectives of the present study were :

1) Assessment of particulate pollution and characterization of the particulates present in the various sections of fibre factories.
2) Assessment of seasonal variations in pollution conditions and their relations to the then prevalent ventilation conditions.
3) Assessment of the effect of particulate pollution on the health and comfort of workers.
4) Evaluation of the adequacy of existing ventilation system to reduce particulate pollution in the working environments of factory rooms.
5) Finding the defects in and suggesting remedies for the present ventilation system, and
6) Suggesting a desirable ventilation system for fibre factories.

4.2 PLAN FOR DETAILED STUDY

The study involved three distinct aspects :

1) Field investigations - Measurements and sampling in fibre factories

2) Laboratory work - Analysis of collected samples for quantitative determination of undesirable items.

3) Theoritical studies - Evaluation of the performance of the present ventilation system and design of a desirable ventilation system for fibre factories.

4.2.1 Field Investigations:

It was proposed to carry out studies in one unit each of the three types of fibre factories, viz., jute, cotton and woollen. The jute factory where the problem of dust pollution inside the factory was apparently much more severe than either cotton or woollen mills was chosen for a relatively more detailed study while in case of the other two mills only skeleton studies could be made in view of the available time and effort.

Details regarding the location and orientation of the selected factories were collected. Meteorological data like wind speed and direction, temperature and relative humidity in the area were collected from the observatory at the Institute of Agricultural Science, Kanpur. For the jute mills, the dimensions of the various sections, locations and

sizes of openings, locations of machinery, etc., were found out and requisite plans and sections prepared. Details of exhausts - their number, locations, capacities, etc., were recorded.

The following measurements and sampling operations were carried out for the assessment of actual situations and for suggesting improvements.

1) Particulate Production and Transport : A detailed study of the various processes was made giving special importance to the mechanism of production and transport of particulates. Effort was made to determine the quantity of air-borne particulates produced by different machines. Estimates were also made of the amount of particulates settled on the floor, the quantities discharged through doors and other openings and that carried away in the exhaust streams.

2) Particulate Concentrations: Concentrations of particulates in the room air were found out using standard sampling methods. For this, the room was devided into grids of convenient sizes and sampling carried out at grid points. The vertical dispersion of particulates was studied by measuring concentrations at different levels (50, 150 and 300 cm.) above floor level. These measurements were carried out during different seasons (in the case of the jute mills) to ascertain the seasonal variations in particulate concentrations.

सकल तारुण्या का उदाहरण—

नेह मद छाई चितवन चतुराई त्यों,
कुमार सुकुमारताई मालती बिसारिए।
गति गरवाई खुलि छाई है गुराई गात,
बातनि सरसताई सुधानिधि धारिए॥
प्यारी के निहार पानि पगनि दगनि लाली,
कोकनद कांति त्यौं गुलाब वार डारिए।
आनन समान नाहीं होत याही दुख माँह,
मुख माँह छाँह छबि-नाह के निहारिए॥

वत्सल-रस का उदाहरण:—

बैन सुन्यो बन तैं हरि आए बने नट-वेष की भाँति गही है।
मात जसोमति द्वारहि दौरि गई सुत देखन कों उमही है॥
कान्हर को मुख चूमति घूमति लाइ हिए निधि मानौ लही है।
आँचर पोंछति गोरज धूलि है फूल हिए सुख भूलि रही है॥

शांतरसानुभाव का उदाहरण:—

जनम गवायौ वादि जित तू सवाद विष,
विषयन मदन विषाद हू अघाइगौ।
कहत 'कुमार' सनसार है असार ताहि
मानि सुखसार अघ औगुन हू छाइगौ॥
चंचल वचंक मन रंचक न जानौ कान्ह,
भवपारावार बीच नीच तू समाइगौ।

1) the weight concentrations of particulates in the various departments of the factories.

2) the particle size distribution - mean sizes by number and weight, standard deviation and percent - fractions of different sizes, and

3) the characterization of the particulates - separation of dust and fibre fractions, fixed and volatile fractions and determination of free silica and microorganisms.

4.2.3 Theoritical Studies :

The velocity distribution and flow patterns inside the factory room are important factors in controlling the particulate pollution. Actual measurement of velocities is very tedious and time consuming. Theoritical computations are possible to determine the velocity distribution inside the factory room for known inlet and outlet conditions. But, even this is difficult because of the complexities produced by the presence of machinery and other fittings, movement of workers and velocities induced by moving parts of machinery. Approximations could be done by treating the inlets and outlets independently and determining the velocity distributions around them and then combining the flow patterns to get an overall picture. In this case care should be taken to balance the inflow and outflow. This approach was followed to determine the adequacy of the present ventilation system and to design a more desirable one for the jute mills.

CHAPTER V

MATERIALS AND METHODS

PART A FIELD MEASUREMENTS

As stated earlier, the study was carried out in three factories - one jute mill, one cotton mill and one woollen mill. The locations of the mills are shown in Fig. 5.1.

5.1 Details of Jute Mills :

The production line of the mill includes softener, carding, drawing, spinning, winding and weaving sections. In the jute mill where ventilation studies were carried out these sections are housed in one hall. The general lay-out of the sections with machinery, fittings, openings and exhausts is shown in Fig. 5.2. The structural details of the production hall are given in Table 5.1.

5.2 MEASUREMENT OF PARTICULATE CONCENTRATIONS

5.2.1 Equipment

The particulate concentrations in the various sections were measured using a M.S.A. Fixt-Flo-Air Sampler (American Conference of Governmental Industrial Hygienists, 1966), an instrument designed for collecting large samples of aerosol contaminants on filters for weighing and analysis in industrial hygiene and air pollution problems. M.S.A. Air Sampling Filters used along with this instrument are made

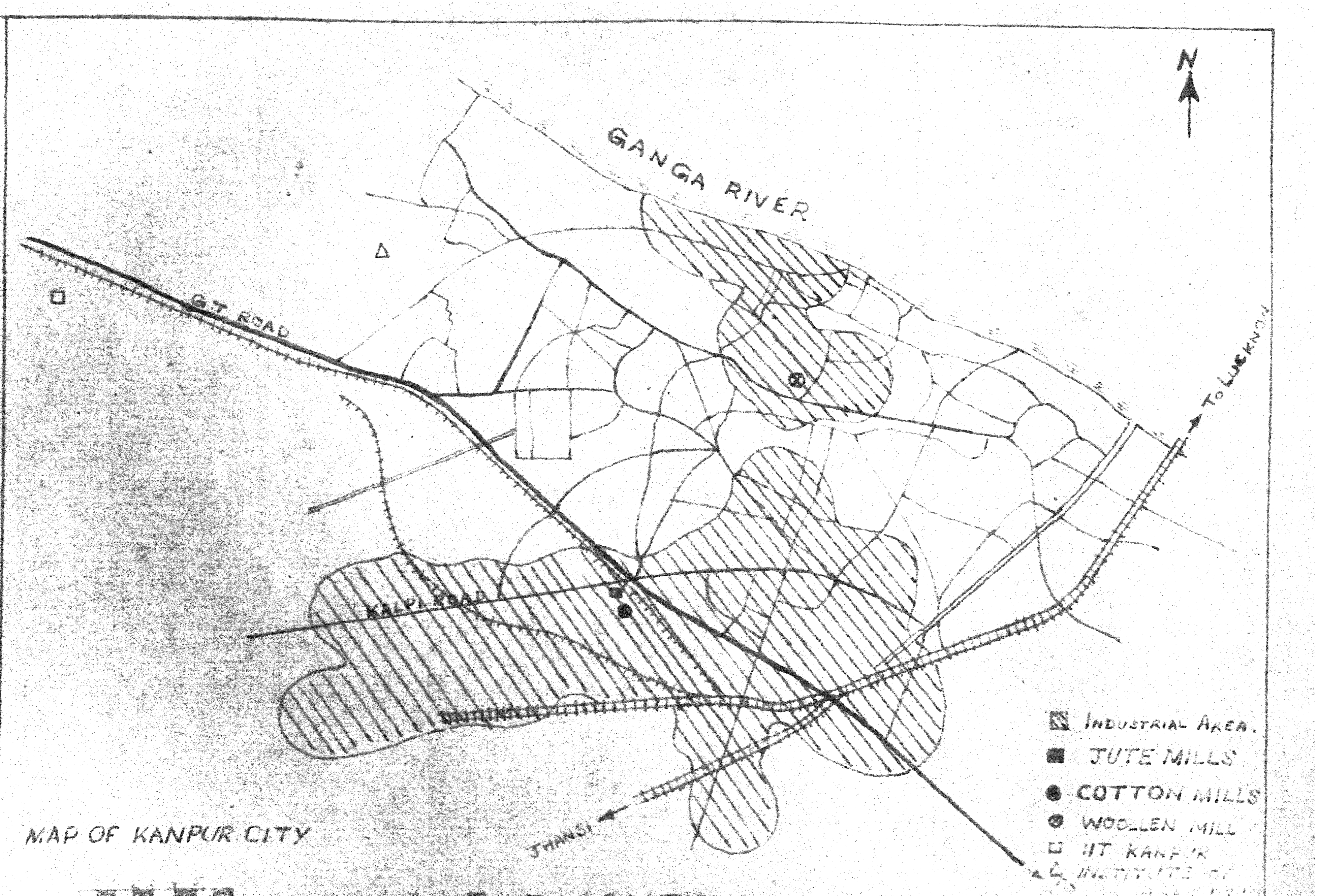


Fig 5.1. LOCATIONS OF MILLS

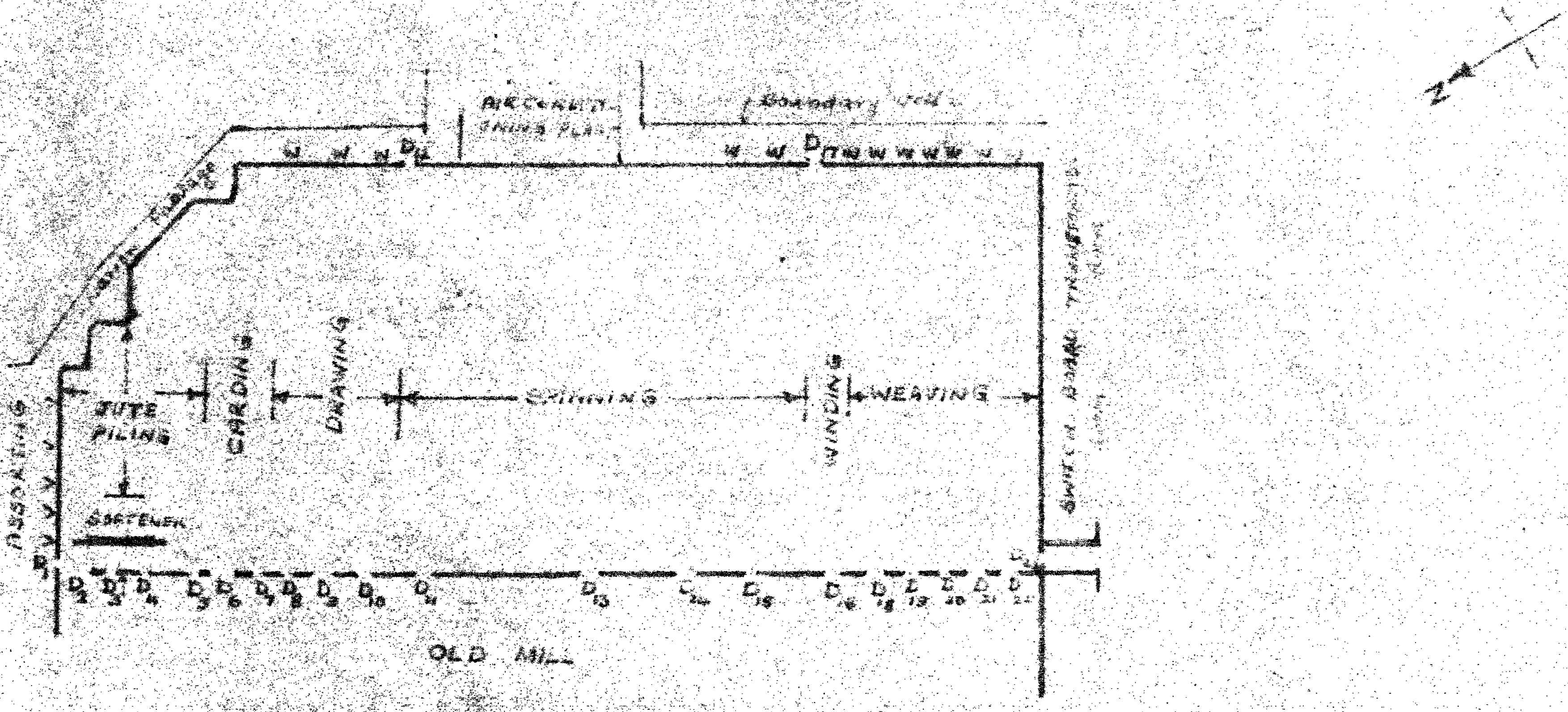


Fig 5.2. GENERAL LAY-OUT
OF FACTORY ROOM [JUTE MILLS]
[NOT TO SCALE].

Table 5.1 Structural and Other Details+ of the Production hall in the Jute Mills where Ventilation Studies were carried out.

Particulars	Dimensions
Production hall size	145 x 38 x 4.5 m (with some irregular shapes at one corner)
Production hall volume	21700 m^3 (net)
Number of doors	23
Number of windows	14
Number of sunlight openings on roof	91
-do- northern side	5
Free area of doors on eastern side	9.06 m^2
-do- on northern and southern sides	8,94 m^2
-do- on western side	140.64 m^2
Free area of windows (all on eastern side)	42.00 m^2 ++
Number of exhaust fans	4
Maximum capacity of exhaust fans	59,200 m^3/hr.
Number of air supply inlets	60
Rate of air supply	298,000 - 430,000 m^3/hr.

+ as on 7 - 4 - 1975. Later modifications not included.

++ The windows are kept open or closed depending on season.

of cellulose, glass fibre or a combination of them.

5.2.2 Sampling Operation:

At the sampling site, a previously weighed filter paper was placed on the suction side of the sampler with its plane side facing the direction of airflow. The sampling was carried out for a particular period of time and the filter paper with sample on it was carefully removed, put in its cover and taken for analysis in the laboratory.

5.3 MEASUREMENT OF VELOCITY DISTRIBUTION

The velocity distribution in the room, at the openings and exhaust were determined by using an Anemotherm - Air Meter (American Conference of Governmental Industrial Hygienists, 1964) and a Vane-Anemometer.

5.3.1 Instruments

a) Anemotherm Air Meter: This is a unique example of hot-wire anemometer used to measure velocities in the range of 10 - 8000 fpm. The probe of the instrument consists of two coils of fine nickel wire which connect through a cable to form arms of a Wheatstone bridge. One of these coils is heated by a separate current passing through a third coil of nichrome wire - in thermal contact but electrically insulated from it - forming a conductive junction. Air passing over the probe element cools the heated wire and varies its

resistance. This is reflected as a variation in air velocity on the pointer type scale. The instrument can be used to measure temperatures ranging from 0 to 255°F by disconnecting the heater current when the unheated wire acts as a temperature sensitive resistance in the bridge circuit. It can also be used to measure static pressure in terms of inches of water from 0 to 10 in. water gauge, positive or negative by a combination of the probe and an auxiliary static pressure cap.

b) Swinging Vane Anemometer (Velometer): It is a portable instrument extensively used in field measurements. It consists of light vanes radiating from a common shaft and set to rotate when facing the wind. The vanes operate a counter which indicate the air speed in fpm. The minimum air velocity should be 200 fpm. for accuracy according to the maker's note of the velometer used.

5.3.2 Procedure:

The Anemotherm Air Meter was kept in operating condition by connecting the probe to the instrument main, selecting the proper range and making the necessary checks. The probe was then held in the direction of air flow and the pointer was read when it became stationary. The procedure was repeated to measure velocities at different elevations

and at different stations. At doors, windows, and exhaust openings where the velocity of flow was more than 200 fpm. velometer was used for the measurement.

5.4 MEASUREMENT OF TEMPERATURE AND RELATIVE HUMIDITY

5.4.1 Instruments

A sensitive mercury-in-glass thermometer with a range of 0 - 100°C was used for the measurement of temperature. A Sling-psychrometer, the simplest form of wet-and-dry-bulb psychrometer was used for determining relative humidity. This instrument has two mercury-in-glass thermometers mounted on a frame and arranged with a swivel-mounted handle at the end so that it can be swung rapidly to give proper air velocity. The wet bulb is covered with a cotton wick which was be wetted with clean water before use.

5.4.2 Procedure:

The wet bulb of the psychrometer was, first, moistened with clean water. The instrument was then swung by the handle for some time and the wet and dry bulb readings were noted. The swinging and reading were continued until two wet-bulb readings agreed. The relative humidity was, then, calculated using a psychrometric table.

5.5 SAMPLING FOR MICROORGANISMS IN FACTORY ROOM AIR

The microorganisms in the factory room air were trapped in a liquid by bubblingthe air through it. Subsequent plating of the liquid and incubation,developed colonies which gave a measure of the number of organisms per unit volume in the room air.

5.5.1 Instruments

a) Midget Impinger: The M.S.A. Midget Impinger (American Conference of Governmental Industrial Hygienists 1966) is a portable hand operated instrument used for dust sampling. This can also be used for determination of air-borne micro-organisms and some gaseous contaminants. It consists of a glass flask partially filled with a liquid. A hand-cranked, four cylinder pump connected to the impinger draws air through it at a relatively high speed. The air strikes at the botton of the flask and the high velocity action causes the dust and other air-borne materials to be 'wetted' and retained in the liquid.

5.5.2 Procedure:

The outlet of the glass flask previously filled with dilution water and sterlized was connected to the hose of the pump with due care to avoid contimination. Air was drawn through the liquid for 5 min. at a vacuum of 10 in.

of water. (The flow rate for this pressure was determined using a wet meter and was found to be 3 liters/min.). After the sampling the openings were plugged with sterilized cotton and the sample was taken for plating. The sampling was carried out at other stations in the section and in all other sections.

PART B LABORATORY STUDIES

The samples collected from the fibre factories were analysed in the laboratory to determine the weight concentrations and size distributions of particulates. The fixed and volatile fractions and the amount of free silica in the particulates were found out. The number of micro-organisms per unit volume of room air was also determined.

5.6 Determination of Weight Concentrations of Particulates

The cover with the filter paper was placed in an oven at 110°C for 2 hours to evaporate off any moisture present, and then decicated and weighed. The particulate concentration at the station was given by :

Particulate concentration (mg/m^3) =(Final weight (mg) - Initial weight(mg))/Vol. of air sampled (m^3)

The sample deposited on the filter paper was carefully collected for further analysis.

5.7 DETERMINATION OF PARTICLE SIZE DISTRIBUTION

The particle size distributions of the samples were determined by microscopic analysis (Allen 1968).

5.7.1 Materials:

a) Microscope: A light microscope with a maximum magnifying power of 2000 was used to measure the sizes of particulates. The resolving power was 0.2 micron. The microscope has an occular scale on which the sizes of particulates could be directly measured. The occular scale was calibrated using a stage micrometer.

b) Preparation of slides: This is the most important part in the microscopic analysis as it decides the accuracy of the analysis. The materials required are :

i) glass slides, cleaned, first, with detergent and clean water, then washed with distilled water and finally with absolute alcohol.,

ii) cover slips similarly treated.,

iii) camel-hair brush, and

iv) glycerol - dispersing medium.

Procedure: Few drops of glycerol were placed on a clean slide. A small quantity of the particulates from a representative sample was put in the glycerol and mixed well with a

camel-hair brush. More glycerol was added to get the required dilution. A drop of the mix was taken on the brush and put on another clean slide. A cover slip was carefully placed over the drop. The slide was then ready for examination under the microscope.

5.7.2 Microscopic examination

The prepared slide was placed on the specimen-stage of the microscope. The sizes of the particulates were measured using the occular scale at 3.5 x magnification. Frequency of particulates of same size was determined by scanning the entire length of the slide. The process was repeated with other magnifications and frequencies of particulates of smaller and smaller sizes were determined. Care was taken to observe the same area of the slide while using all the magnifications.

5.7.3 Mean sizes and Standard Deviation:

The cumulative percent of the number of size fractions starting from the smallest were plotted against log sizes on a log-probability paper. A straight line was fitted through the points, giving more importance to the points near the 50 percent region. The particle size corresponding to 50 percent cumulative gives the geometric mean size by number. The standard deviation is given by the ratio of the

size corresponding to 84.13 percent and the mean size. The geometric mean size by weight was determined using the formula (Hatch, Choate 1929),

$$\log \overline{d_{wg}} = \log \overline{d_g} + 6.908 \log^2 s_g.$$

where,

$\overline{d_{wg}}$ = the geometric mean size by weight (μ)

$\overline{d_g}$ = geometric mean size by number (μ), and

s_g = standard deviation, which will be the same for both distributions.

5.7.4 Percent Fractions by Weight:

The percent fractions by weight could be found out directly by separating the fractions from the sample by sieving, elutriation, hydrometric analysis or by use of instruments like cascade impactor. These operations require large sample. Also methods like elutriation allows flocculation of particulates and the fractions separated may not be true fractions of actual sample. It could also be determined indirectly by using plots of cumulative percent by number vs particle size.

In the case of settled particulate large quantities were available and sieving was the method followed for analysis.

U.S. standard sieves were used for this purpose. The relation between the screen mesh and particle size is given in Table 5.2.

Table 5.2 Relation of Screen Mesh to Particle Size

U.S. Standard Sieve Mesh	400	325	275	200	140	100	75	60	35	18
Nominal Sieve Opening in Microns	37	44	53	74	105	149	208	250	500	1000

For samples collected from room air the quantities were too little to go for any method other than an indirect microscopic method. In the plot of cumulative percent fractions by number vs particle size, the computed value of geometric mean size by weight was marked on the 50 percent line. A line parallel to number size distribution line was drawn through this point. This line can be taken to represent the size distribution of particulates by weight. The percentages of different size fractions were directly read from the plot.

5.8 CHARACTERIZATION OF PARTICULATES

5.8.1 Fixed and Volatile Fractions in the Particulates:

Known quantities of samples were kept in weighed nickel crucibles. The crucibles with samples were kept in a

muffle furnace at 600°C for 2 hrs. They were, then, removed from the furnace, decicated and weighed. The loss in weight is due to the burning of volatile fractions. The percentages of fixed and volatile fractions could then be calculated.

5.8.2 Determination of Free Silica:

The method described by Durkan (1946) was used for the determination of free silica in the particulates of the factory room air. The method includes HCl digestion, H_3PO_4 digestion and dilute HF treatment.

5.8.3 Microorganisms in the Particulates:

a) Medium for Sampling: The medium for sampling was prepared as per specifications given in Standard Methods (American Public Health Association 1971). 1.25 ml of stock phosphate buffer solution was added to 1 liter of distilled water to make the dilution water. The stock phosphate buffer solution was made by dissolving 34.0 g of potassium dihydrogen phosphate (KH_2PO_4) in 500 ml distilled water. The pH was adjusted to 7.2 with 1N, NaOH and the solution was diluted to 1 liter with distilled water.

b) Procedure: The samples collected from various sections of of the factory were plated and incubated and total plate count made as per specifications given in Standard Methods (American Public Health Association 1971).

Dilutions of samples were made by transferring 1 ml of the original sample to 99 ml of dilution water and then 1 ml of this diluted sample to 99 ml of dilution water. 1 ml of sample from the specimen and two dilutions were transferred to petri dishes. Three plates were made for each sample and for each dilution. They were then incubated at $35 \pm 2^{o}C$ for 24 ± 2 hrs. The counts were made using a bacterial colony counter.

PART C THEORITICAL STUDY

The experimental studies alone may not give a complete picture of the phenomena of particulate transport and room air movement. So a theoritical approach also was attempted.

5.9 PARTICULATE TRANSPORT

5.9.1 Settling Property of Particles:

When a discrete particle falls through a medium (air, in this case) under the influence of gravity it will be acted upon by two forces viz. the gravitational force and the resistance of the medium. Under the influence of these forces the particle accelerates for a short distance and then settles at a uniform terminal velocity when the resisting force equals the gravitational force. The gravitational force is a constant for a particular particle and

is given by

$$F_g = (\rho_p - \rho_a)gV.$$

where,

F_g = gravitational force,

ρ_p = mass density of the particle,

ρ_a = mass density of the air medium,

g = gravity constant , and

V = volume of the particle.

The resistance of the medium is a function of the dynamic viscosity, μ, and mass density ρ_a of the air and the velocity v_s and characteristic diameter d_p of the particle. Dimensionally, the resisting force may be expressed as :

$$F_R = \varphi(v_s, d_p, \rho_a, \mu)$$

Introducing fundamental units and solving, we get

$$F_R = v_s^2 d_p^2 \rho_a \varphi(v_s d_p \rho_a / \mu)$$

$$= v_s^2 d_p^2 \rho_a \varphi(R_e)$$

where R_e is the Reynolds number.

Substituting A, the cross sectional or projected area for d_p^2, $\rho_a v_s^2/2$, the dynamic pressure for $\rho_a v_s^2$, and C_D, Newton's drag coefficient for $\varphi(R_e)$

$$F_R = \frac{C_D A \rho_a v_s^2}{2}$$

The magnitude of C_D varies with R_e and for spherical particles may be approximated as (Camp 1946)

$$C_D = \frac{24}{R_e} + \frac{3}{R_e^{\frac{1}{2}}} + 0.34$$

Equating the gravitational force and resisting force, the terminal velocity is given by

$$v_s = \left\{(2g/C_D)[(\rho_p - \rho_a)/\rho_a](V/A)\right\}^{\frac{1}{2}}$$

For spherical particles,

$$v_s = \left\{\left(\frac{4}{3}\, g/C_D\right)\left[\frac{\rho_p - \rho_a}{\rho_a}\right] d_p\right\}^{\frac{1}{2}}$$

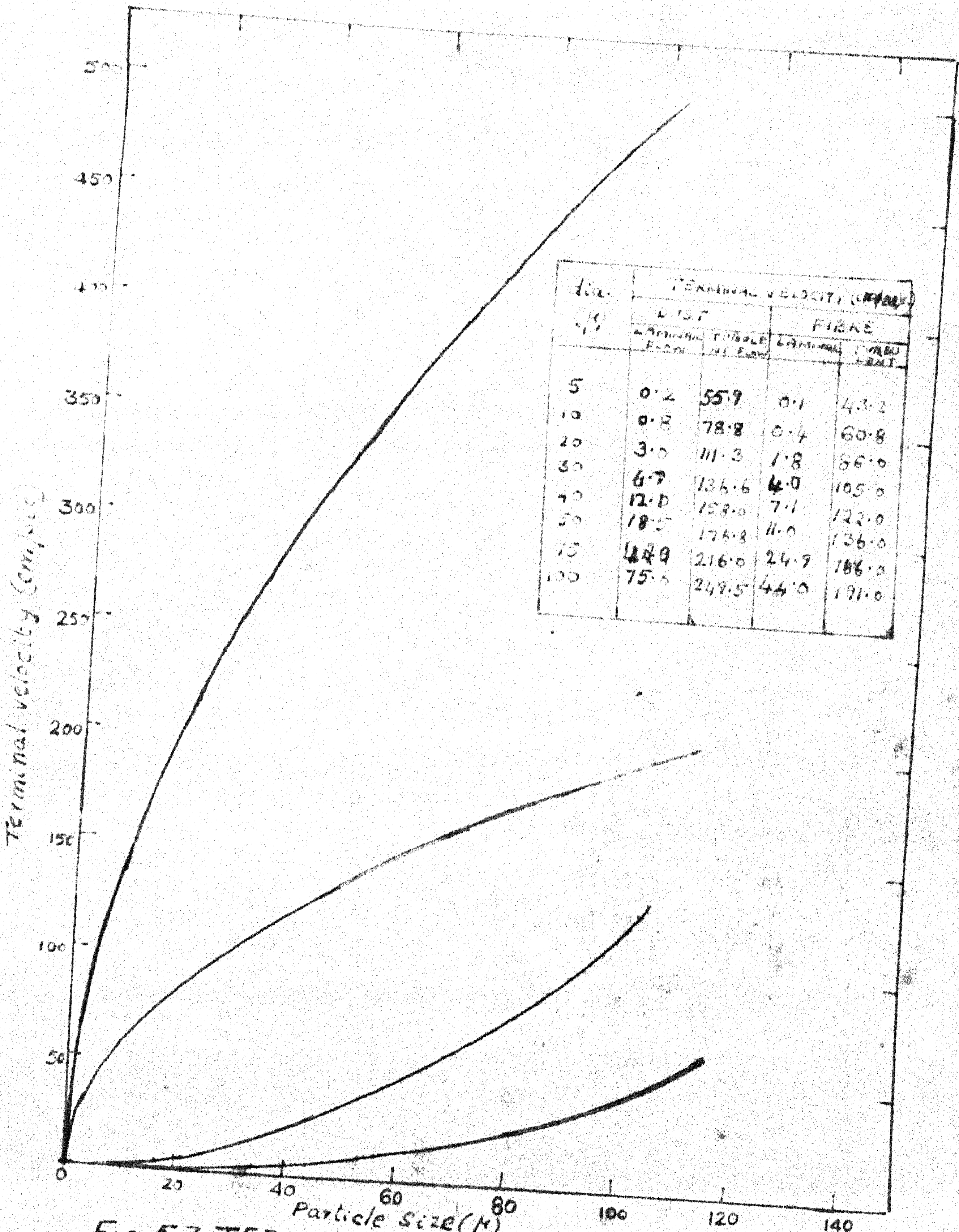
For high Reynolds number ($R_e = 10^3$ to 10^4 and $C_D = 0.4$) the flow is turbulent and

$$v_s = \left[3.3\, g \left(\frac{\rho_p - \rho_a}{\rho_a}\right) d_p\right]^{\frac{1}{2}} \quad \text{(Fair et al 1968)}$$

For laminar flow conditions at low Reynolds numbers ($R_e < 0.5$, and $C_D = 24/R_e$), the terminal velocity is given as

$$v_s = \frac{g}{18\,\mu}\left(\rho_p - \rho_a\right) d_p^2$$

The terminal velocities of particulates under the laminar and turbulant flow conditions are given in Fig. 5.3.



dia. (μ)	TERMINAL VELOCITY (cm/sec)			
	DUST		FIBRE	
	Laminar Flow	Turbulent Flow	Laminar	Turbulent
5	0.2	55.9	0.1	43.2
10	0.8	78.8	0.4	60.8
20	3.0	111.3	1.8	86.0
30	6.7	136.6	4.0	105.0
40	12.0	158.0	7.1	122.0
50	18.5	176.8	11.0	136.0
75	44.0	216.0	24.9	166.0
100	75.0	249.5	44.0	191.0

FIG. 5.3 TERMINAL VELOCITIES OF SPHERICAL PARTICLES

According to Ingersoll et al. (1956) the settled particles will be removed when the velocity of flow exceeds certain limits. The displacement velocity is given by;

$$v_d = (8/f)^{\frac{1}{2}} v_s$$

where,

v_s is the settling velocity and f is the Weisbach-Darcy friction factor. For $f = 2.5 \times 10^{-2}$, v_d should be below 10 v_s (Fair et al. 1968). ,if the particles have not to be moved.

5. 9 .2 <u>Inertial Property of Particulates:</u>

A particle projected with a certain initial velocity will be acted upon by the frictional resistance of air and its speed will be reduced in accordince with the distance-velocity relationship (Hemeon 1963).

$$\delta s = \int_{u_o}^{u} \frac{u\ du}{g - \frac{C_D \rho_a A u^2}{2\ W}}$$

where ,

δs is the distance travelled by the particle when the initial velocity u_o is reduced to u, and W is the weight of the particle.

For turbulent flow where C_D is 0.44, the integration of the equation will give,

$$\delta s = \frac{7\rho_p}{\rho_a} \cdot d_p \cdot \log_{10} \frac{u_o}{u}$$

Substituting for ρ_a and expressing d_p in microns

$$\delta s = 93 \times 10^{-4} \rho_p \, d_p \log_{10} \frac{u_o}{u}$$

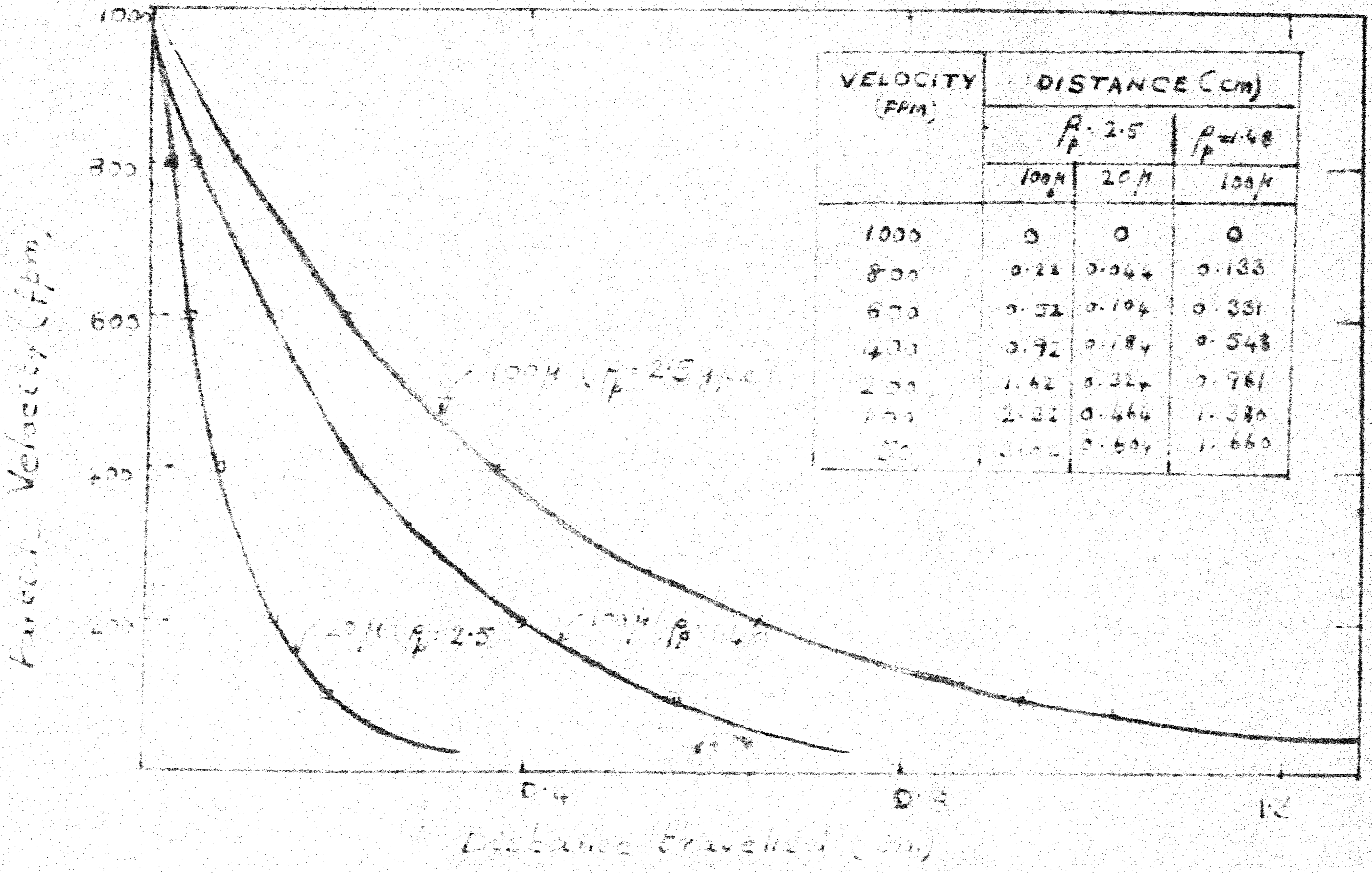
The distance travelled by particles of 20 and 100 μ dia. with density 2.5 g/c.c. and that of 100 μ dia. with density 1.47 g/c.c. (Mantell 1958) are shown in Fig. 5.4.

5.10 VELOCITY DISTRIBUTIONS AT INLETS AND OUTLETS

In a mechanical ventilation system air is extracted from space through exhausts and compensating air is supplied through supply inlets. The pattern of air flow depends upon inlet and outlet positions, the rate of flow and the interior conditions. As far as the factory room being studied was concerned, the interior conditions are so complex that it is almost impossible to use a theoritical approach to determine accurately the complete flow pattern. Still, making the assumptions that the inlets and outlets function independently (which, never, is the case), the flow pattern for these may be combined to get an overall picture.

5.10.1 Velocity Distribution at Inlets:

Air into occupied spaces is usually supplied in the form of jets. To predict the velocity distribution in the jet-stream, the basic relations of the continuity equation, the equation of motion, and the conservation of total



VELOCITY (FPM)	DISTANCE (cm)		
	ρ_p = 2.5		ρ_p = 1.48
	100μ	20μ	100μ
1000	0	0	0
800	0.21	0.044	0.133
600	0.52	0.104	0.331
400	0.92	0.184	0.548
200	1.62	0.324	0.961
100	2.32	0.464	1.380
50	[illegible]	0.604	1.660

FIG 5.4 DISTANCE REACHED AND VELOCITY OF SPHERICAL PARTICLES PROJECTED WITH INITIAL VELOCITY OF 1000 FPM.

momentum in the direction of flow are made use of. Schlichting (1958) found a relation for the velocity at a radius r from the centre line of the jet at a distance of x from the face as

$$u = \frac{7.41\sqrt{J/\rho}}{x[1+57.5(\frac{r^2}{x^2})]^2}$$

where,

J = total momentum, and

ρ = density of air

Along the centreline the value of r is zero and u become u_{cl}, the centreline velocity at x.

$$u_{cl} = \frac{7.41\sqrt{J/\rho}}{x}$$

Substituting for $J = u_o^2 A_o$, where A_o is the face area and u_o is the face velocity of the jet,

$$u_{cl} = \frac{7.41\sqrt{A_o}\, u_o}{x}$$

or, in general,

$$u_{cl} = \frac{K\sqrt{A_o}\, u_o}{x}$$

where K is a constant whose value varies from 5 to 7 (Tuve 1953).

The air entrainment ratio at any distance x is given by

$$\frac{q_x}{q_o} = \frac{u_o}{u_{cl(x)}}$$

Applying these equations, the flow pattern in the jet stream was found out.

5.10.2 Velocity Distribution at Outlets:

The discharge through an outlet opening is given by the product of its area and the velocity of flow.

$$Q_o = A_o V_o$$

where Q_o is the rate of flow, A_o is the free area of outlet and V_o is the face velocity.

Assuming that air enters through an imaginary spherical surface, the velocity at any distance can be obtained by equating the flow through the outlet and that through the imaginary spherical surface, at that distance.

$$A_o V_o = A_x V_x$$

The imaginary spherical surface may be a whole sphere, hemisphere, quarter sphere, or any other fraction of a sphere depending on the number and position of flanking planes. An emperical relation for the discharge at a distance x

is given by Dalla Valle (1946) as

$$Q_x = V_x(10X^2 + A_o)$$ for plain outlets. For flanged outlets,

$$Q_x = 0.75\ V_x(10X^2 + A_o)$$

where A_o is the face area of the outlet.

Silverman and Leslie (1942) give the exhaust air volume for plain slots with aspect ratio ($\frac{W}{L}$), 0.2 or less as

$$Q = 3.7\ LVX$$

and for flanged slot of same aspect ratio as

$$Q = 2.8\ LVX$$

where L is the length of the slot V is the velocity at a distance X.

Applying these equations the velocity distributions in areas of interest were determined. The transport of particulate for the flow patterns developed and hence, the efficiency of a ventilation system in controlling particulate pollution were found out.

A more rigorous method would be the application of Laplace's equation (Robertson 1965) to determine the velocity distribution in the whole room for assumed inlet and outlet conditions and to choose the ideal one from considerations of economy and efficiency.

5.11 AIR FLOW UNDER NATURAL VENTILATION CONDITION

Under natural ventilation condition, air flows into and out of a room by the action of either wind or temperature difference between the inside and outside of the room or by a combined action of the two.

5.11.1 Air flow due to wind :

The quantity of air forced through a ventilation opening by the action of wind, is given by the equation (Randall and Conover 1931),

$$Q = EAV$$

where,

Q = air flow, cfm

A = free area of inlet opening, sq.ft.

V = wind velocity, fpm; and

E = effectiveness factor (0.5 to 0.6 for perpendicular wind and 0.25 to 0.35 for diagonal wind)

5.11.2 Air flow due to temperature difference :

When temperature in a building is different from outside temperature pressure difference between inside and outside occurs as a result of difference in air density. This is called chimney effect and it causes inward or outward flow given by the equation,

5.12 CONCENTRATION TRANSPORT

Concentration, as temperature, moves from a higher state to lower state.

5.12.1 Horizontal transport :

The percent decrease of concentration in the horizontal direction is given by the equation

$$\frac{-dC}{dL} = \lambda C$$

where C concentration at distance L,

L = Distance from source and

λ = transport coefficient.

Integration of the equation gives the result,

$$\log \frac{C_o}{C} = \lambda L.$$

A plot of $\log \frac{C_o}{C}$ $V_s L$ gives a straight line and the value of λ can be found out.

The same equation may applied for vertical transport with L changed to Z, where Z is the height.

5.12.2 Transport due to eddy Diffusion :

If a turbulent flow raises particles deposited in a duct a distribution of them becomes established along the

height. The upward movement of particles by eddy diffusion through an area of 1 cm^2 in 1 sec is given by $-D_t \frac{d_n}{d_z}$ where D_t is the eddy diffusion. The downward movement of particles by gravity through the same area for 1 sec is given by

$V_s n$, where V_s is the settling velocity and n is the concentration.

Equating the expressions (Fuchs 1964)

$$\frac{dn}{n} = - \frac{V_s}{D_t} dz,$$

Whence

$$\ln \frac{n}{n_o} = - V_s \int_o^z \frac{dz}{D_t}$$

For the central region where D_t is almost constant, the equation takes the form

$$\ln \frac{n}{n_o} = - \frac{V_s z}{D_t}$$

Where n_o is the concentration at the bottom and n, the concentration at height z.

For a particular sample taking V_s as the settling velocity of mean size particles and substituting in the equation, it takes the form of equation given in 5.12.1. The value D_t, the eddy diffusion coefficient can thus be determined.

CHAPTER VI

RESULTS AND DISCUSSIONS

PART A PARTICULATE POLLUTION AND HAZARDS

6.1 POLLUTION HAZARDS IN THE JUTE MILLS

6.1.1 Particulate Concentrations in various sections of a jute mill and seasonal variations therein

Fig. 6.1 shows the seasonal variations of particulate concentrations in the various sections of the jute mill. The following points can be noted from the graph.

a) The particulate concentrations in the softener and carding sections are high compared to the drawing, spinning and weaving sections. As exhausts are also provided in softener and carding sections, the higher concentrations are obviously due to the major sources of pollution being located in these sections.

b) Considering the variation in the particulate concentrations from the softener section end (starting end) of the factory and moving towards the weaving end (other end), one can find that, in general, there is a trend of decrease in concentrations. This is especially true for the case of summers as indicated by the curve for April. During this month, cool and humidified air is admitted

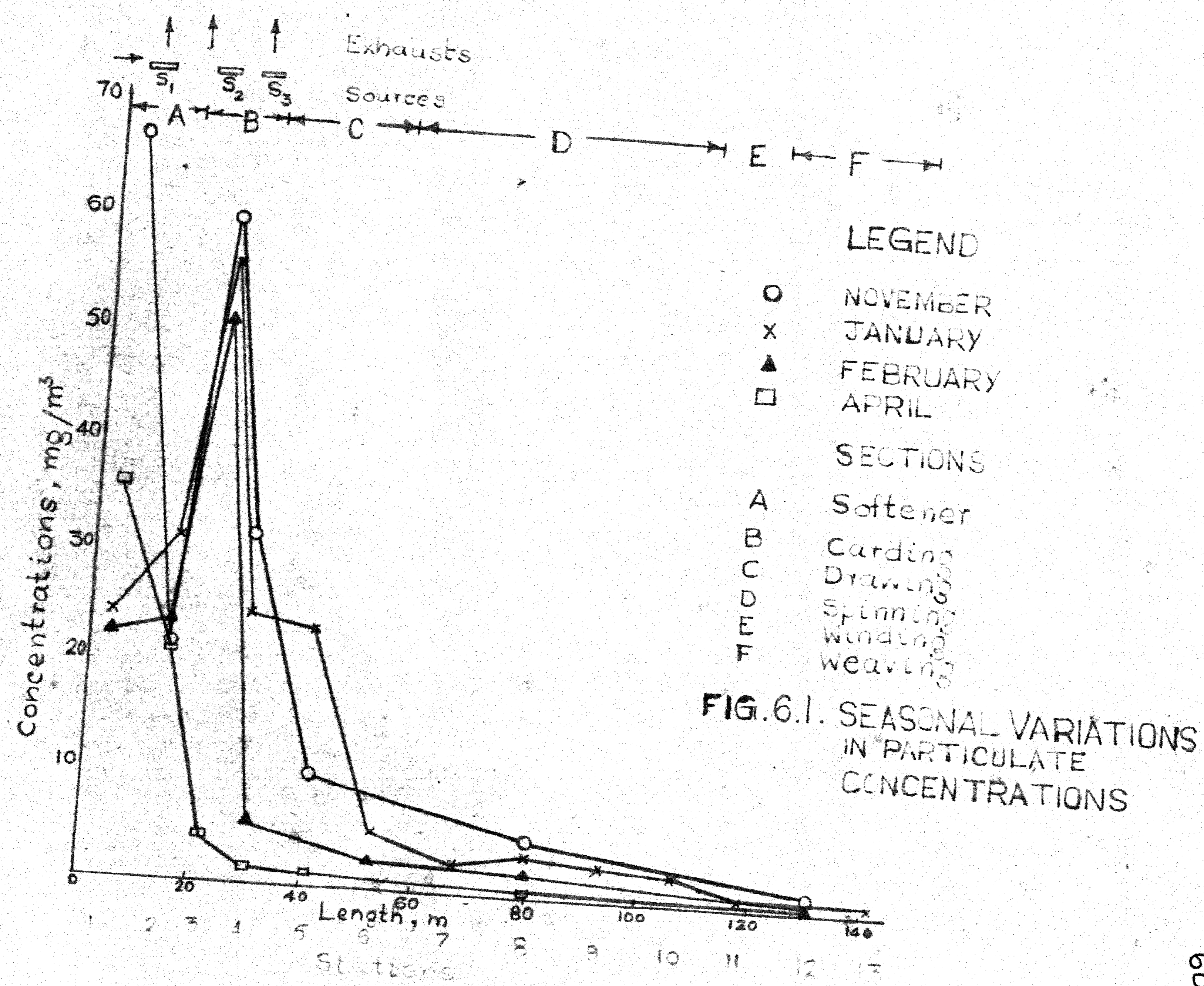


FIG. 6.1. SEASONAL VARIATIONS IN PARTICULATE CONCENTRATIONS

into the room which leads to lesser production of particulates and also their rather quick removal by increased ventilation.

c) In seasons other than summer, when cold humid air is not admitted, the maximum particulate concentration seems to be reached between the carding machines situated a short distance downstream of the softener end. This, obviously, would be due to the large amount of particulate production during carding. It should be noted that this condition does not apply to the curve for April when only very little dust seems to be produced during carding. The particulate concentration during April was recorded to be 4.0 mg/m^3 as against 50 - 59 mg/m^3 for the other three months. Due to limitation of time no observations could be taken during the rainy reason. However, it is expected that due to higher humidity the particulate concentrations during the months from pril to September will follow, generally, the pattern of the curve for April.

d) In the short distance from the starting end up to station 2 the particulate concentration variations seem to be slightly erratic. This may be due to the different relative qualities of particulates produced between the softener and carding sections and due to different

amounts of humidity and ventilation present in these sections. Whereas for the curve of April, there is a steep and almost straight-line decrease in particulate concentration from 35 mg/m^3 at station 1 to 4 mg/m^3 at at station 3, for the curve for November one finds a decrease from station 1 to station 2 and then an increase from station 2 to station 3. For the curves for January and February, even between stations 1 and 2, there is a slight increase. This may be due to a relatively higher production of dust in the carding section as compared to the softener section.

e) As one moves from station 3 to station 4 there is a rather sharp decrease in concentration during February compared to other seasons. This is due to the opening of windows at the beginning of the drawing section during this season. The outside air, then, flows across the length of the room reducing the transport of particulates into the finishing sections.

f) Considering the overall variations and knowing the humidity ventilation patterns, it is felt that concentration variations can be devided into two seasonal catagories. This inference is made from the point that the curves for November, January and February are not only similar in

terms of general trends but also the values at any particular station for these three curves are rather close. The ranges of particulate concentrations at different sections can thus be predicted to be of the order given in Table 6.1. If one were to assume the expected ranges as given, it would seem that, the particulate concentrations during October to March will be much higher and the dust problems in summer would be less because of cold air inlet and also during rainy season because of natural humidity.

6.1.2 Variations of Particulate Concentrations with Height

Figs. 6.2 and 6.3 show variations in particulate concentrations with height in the different sections of the jute mill during the month of January 1975. The following points are observed from Fig. 6.2.

a) The concentrations, in general, at any station decrease with height, the gradients depending on the height of source, presence of exhaust and other openings, and the nature of pollutant.

b) At heights of 50 cm and 300 cm above floor level, the particulate concentrations were found to be decreasing as one moves from station 1 to station 2. But at 150 cm height, the concentration increased as one proceeds from station 1 to station 2. The explanation for this is the fact

Table 6.1 Expected particulate concentrations at breathing height (150 cm above flow) at worker positions in various sections of a jute mill

Station	Section	Distance from beginning end (m)	Expected concentrations (mg/m^3)		
			October to March	April to September	Ratio
1.	Softener	4.0	20 - 70	About 35	0.6-2.0
2.	Carding (beginning)	14.5	20 - 30	" 20	1.0-1.5
3.	Between Carding machines	21.5	50 - 60	" 4	12-15
4.	Drawing (beginning)	28.5	5 - 30	" 1.5	3-20
5.	Drawing (middle)	41.0	4 - 23	" 1.0	4-23
6.	Spinning	80.0	2 - 5	" 0.8	2.5-6
7.	Weaving	131.0	1 - 1.5	" 0.5	2-3

that the concentration at station 2 at a hight of 150 cm is contributed by the carding machines with source at a height around 1.5 m above flour level, rather than being transported from the softening section.

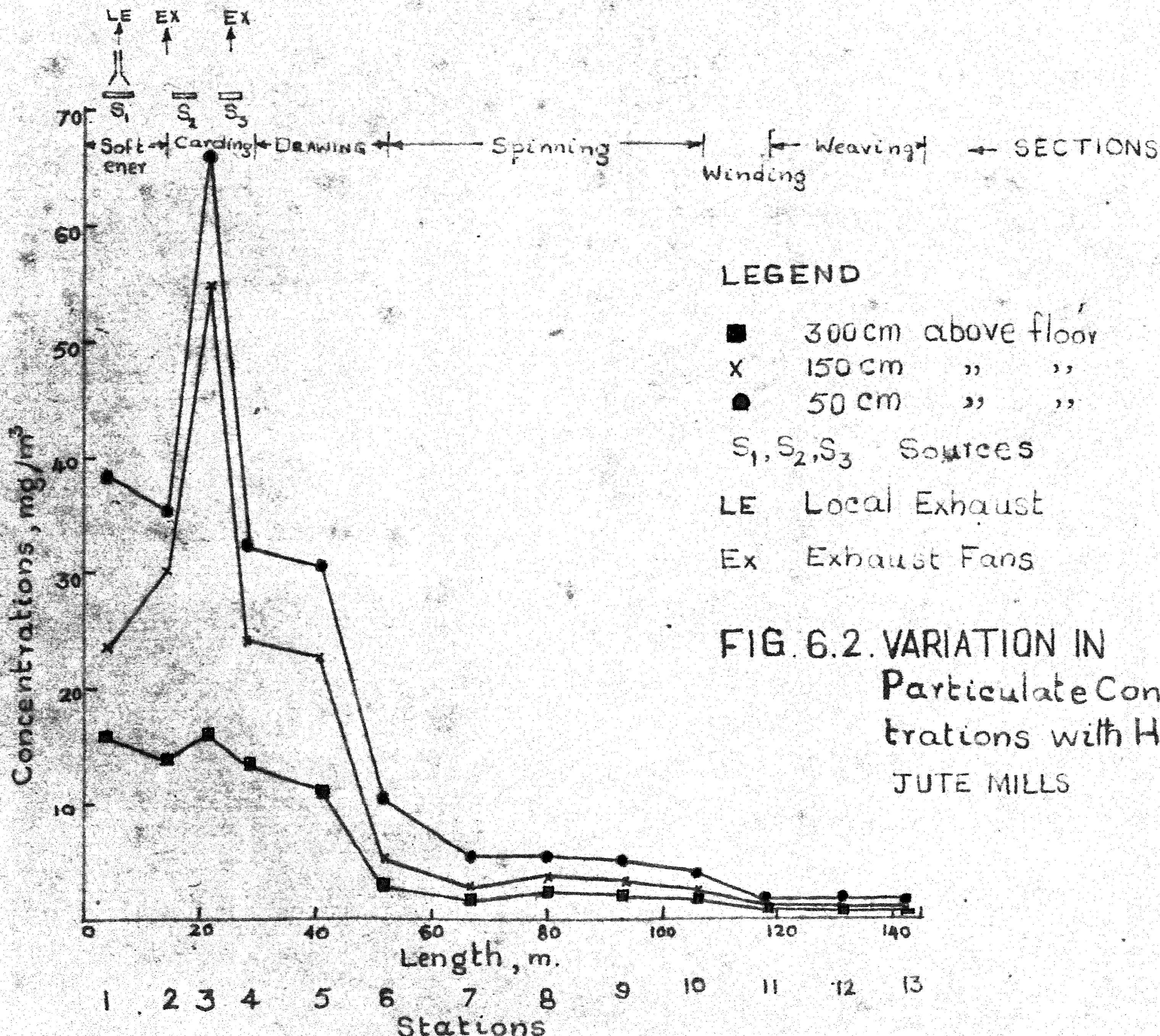


FIG. 6.2. VARIATION IN Particulate Concentrations with Height
JUTE MILLS

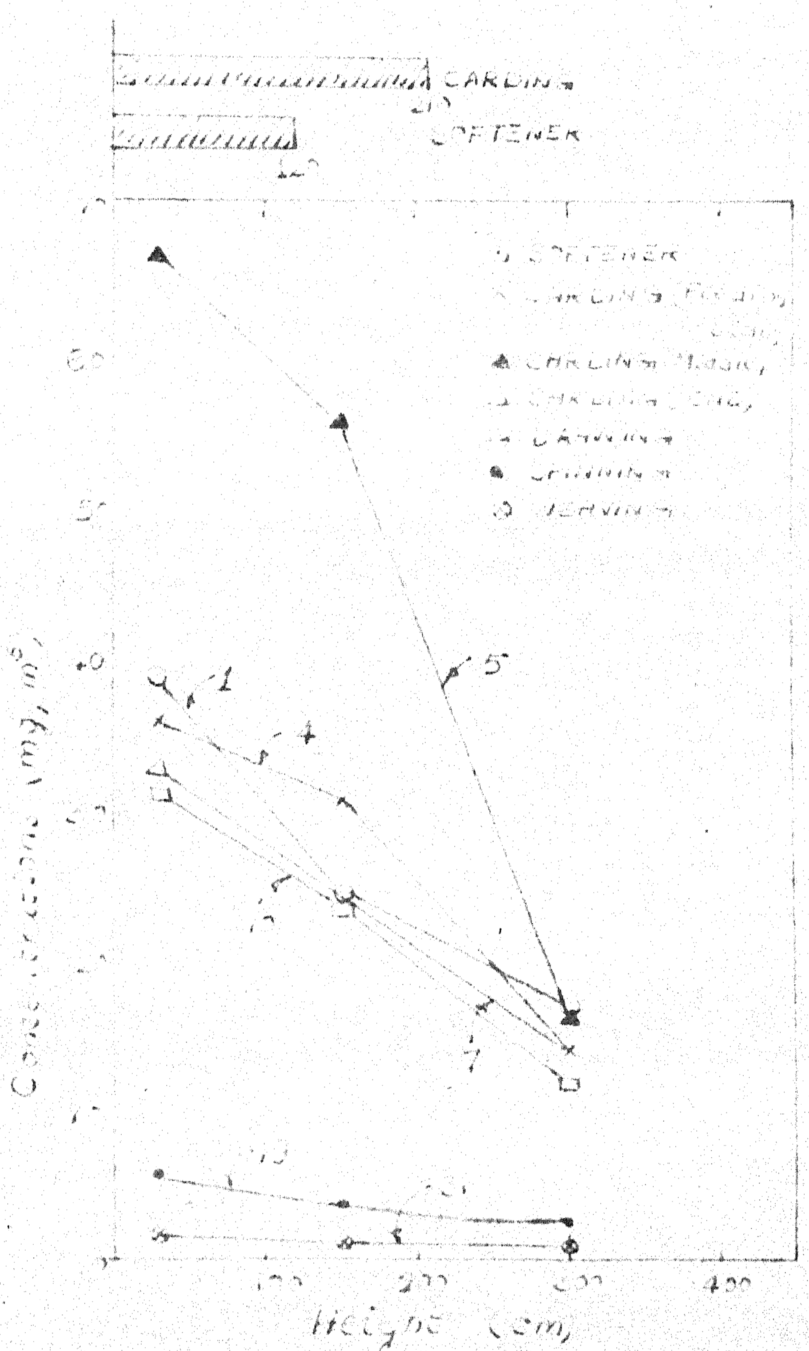


FIG. [illegible] CONCENTRATION GRADIENTS ALONG HEIGHT – JUTE MILLS

c) The higher concentrations between the carding machines is as expected. The relatively higher concentration at 50 cm level is due to the settling of bigger and heavier particulates produced in this section. The concentration at 150 cm is high because of the higher elevation of the sources. Presence of exhausts on the roof explains the lower concentration at 300 cm height.

d) For all heights observed the concentrations in the spinning section are low and uniform because of the lower production and good mixing by the turbulance in air produced by spinning machines. In weaving section also the concentrationsare low and uniform due to the same reasons.

Fig. 6.3 shows the concentration gradients along the height of the room in various sections during January. The following inferences could be made from the graph.

a) In the softener area steeper gradients are seen in the first 150 cm height compared to the next 150 cm height. This may be due to the settling of heavier particulates to the bottom, the lower height of source, the cross draught produced by the low wind blowing in through the door and the local exhaust provided over the softener.

b) Curves 4, 5 and 7 show the variations in concentrations in the carding section. The influence of the exhaust fans

on roof is given by the shapes of curves 4 and 5. The concentrations at higher elevations are considerably reduced by the constant removal of pollutants. The lower points are comparatively less influencedby exhaust fans indicated by the relatively flatter gradients similar to those in other areas.

c) Curves 10, 19 and 31 show the variations in sections where no exhaust arrangements are provided. The variation was found to be uniform and almost of same nature in all the three sections.

6.1.3 Hygienic significance of particulate size distribution

Figs. 6.4 and 6.5 show the size distributions of dust and fibres respectively in the room air in various sections of the jute mill. The mean sizes and percentages of dust and fibre of hygienic importance are shown in Table 6.2.

The following points could be noted in the results :

a) The mean sizes of dust are maximum in the softener and carding sections of the mill. This could be expected because the bigger particles are easily removed from the jute and hence their percentage will be more in the initial stages of processing.

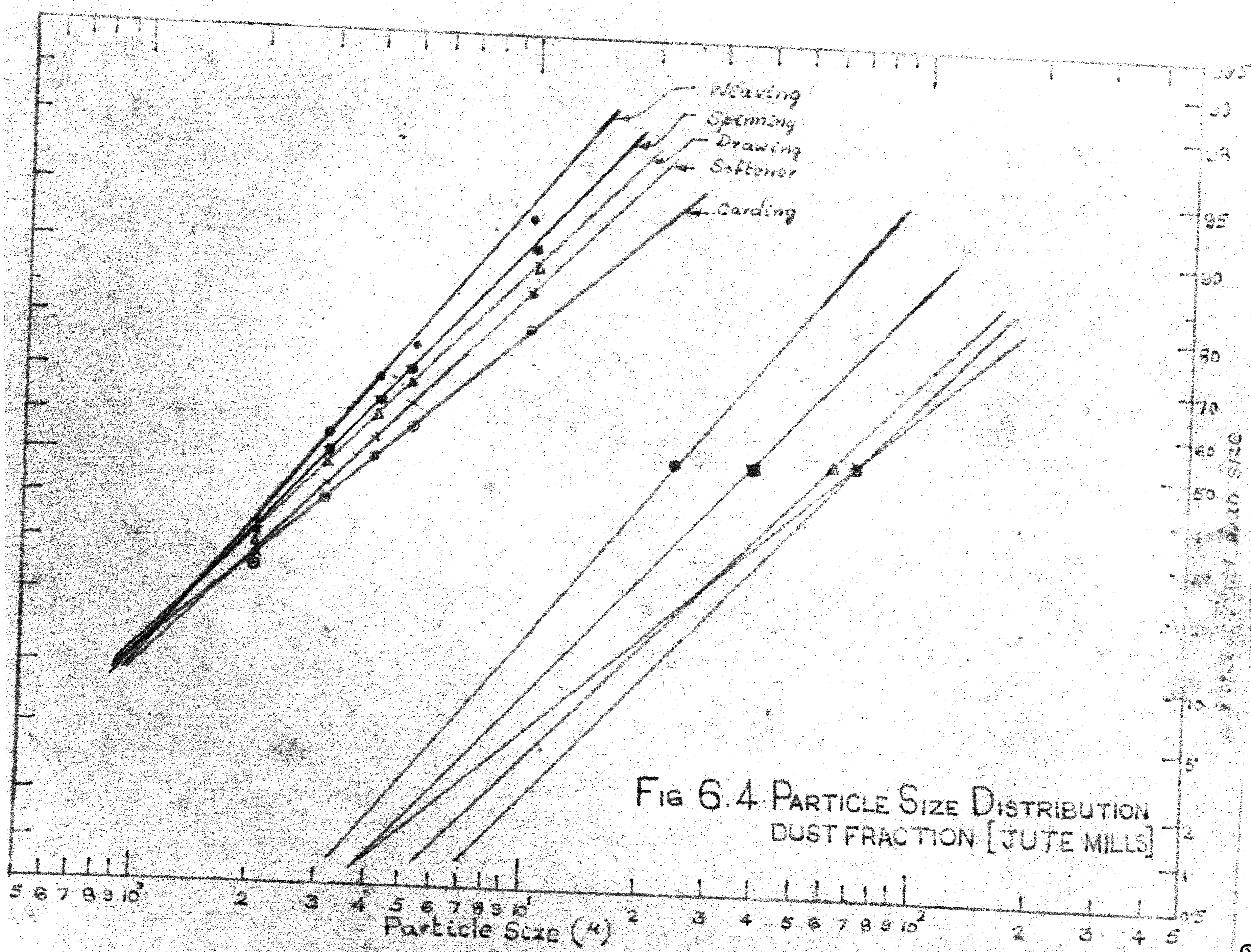


Fig 6.4 Particle Size Distribution
Dust Fraction [Jute Mills]

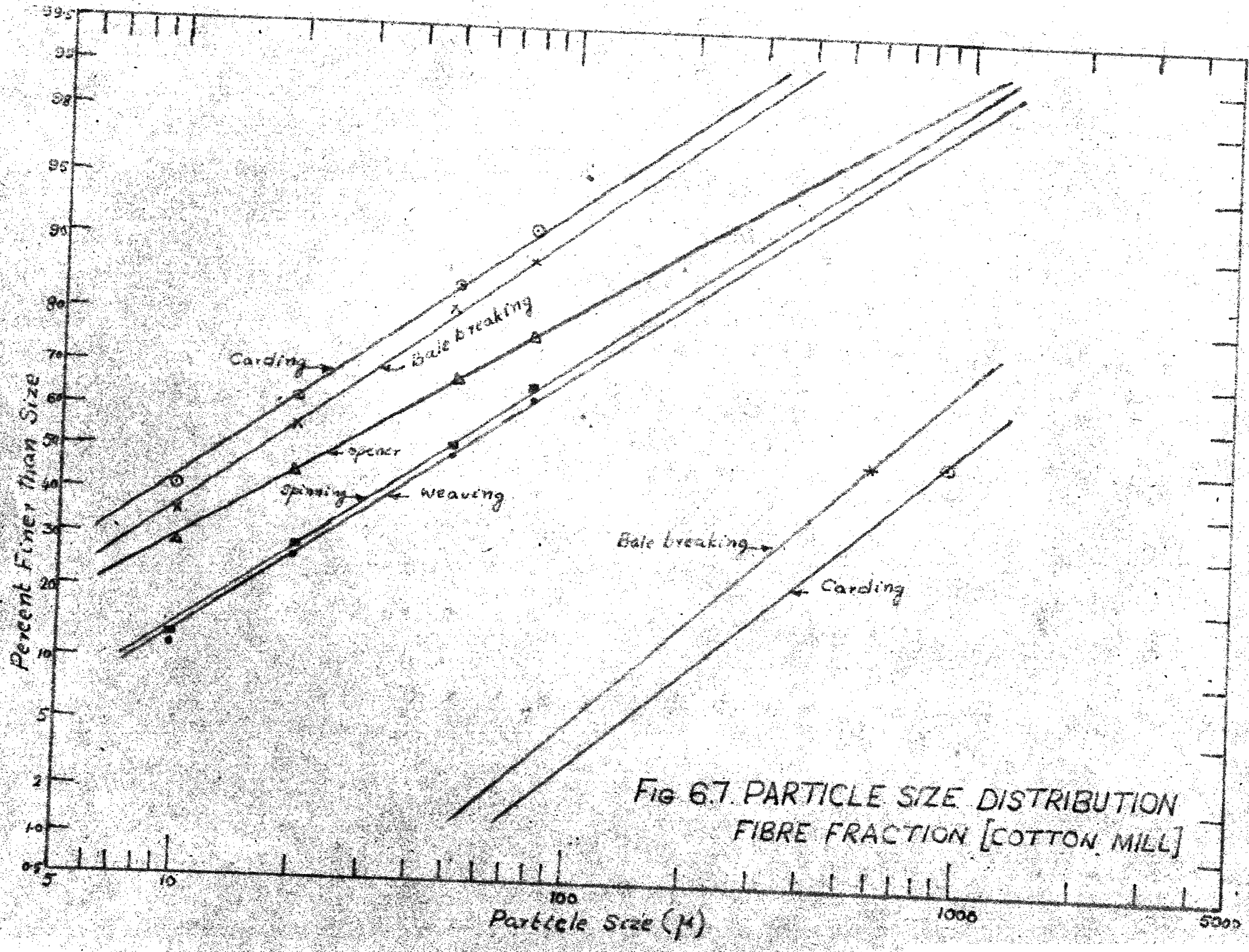


FIG 6.7 PARTICLE SIZE DISTRIBUTION
FIBRE FRACTION [COTTON MILL]

Table 6.2 Hygienic significance of particulates in jute mill room air

Section	Range of particulate concentration (mg/m^3)	Geometric mean size by number (μ)	Standard deviation	Geometric mean size by wt.	%by wt of particulates <10μ	%by wt. of part. <6μ	wt. retained in workers lungs (μg/day)
DUST FRACTION							
Softener	21.0-66.0 +	3.60	2.70	68.60	2.3	0.5	162.5-510.0
Carding	4.5-78.0	4.00	2.70	67.90	5.0	1.8	73.0-1265.0
Drawing	2.1-30.6	3.10	2.70	59.10	3.5	1.0	10.8-161.2
Spinning	1.5- 5.8	2.90	2.50	36.00	8.0	2.4	9.3- 36.0
Weaving	0.5- 1.6	2.70	2.30	23.52	15.0	4.6	4.1- 13.0
FIBRE FRACTION							
Softener	As above	18.00	3.70	2663.00	0.1	negl.	negligible
Carding	'	25.60	6.20	547300.00	0.1	'	'
Drawing	'	65.00	7.50	665100.00	negl.	'	'
Spinning	'	74.30	4.30	42760.00	'	'	'
Weaving	'	81.10	4.20	38770.00	'	'	'

+ a maximum concentration of 135.0 mg/m^3 was observed in the softener section of the old mill of this factory.

b) The mean sizes of dust were found to be reducing from one station to another as one moved from the softener section to the weaving section. The reduction was more in the initial stages compared to later stages. This is because of the removal of heavier particles in the initial stages, mainly by settling. The removal of smaller particles by settling is not easy. Also they move with the air medium and hence the lower variation in mean sizes in the latter sections.

c) In the case of fibre fractions the mean sizes were found to be increasing as one moved from softener to weaving sections. This is because bigger and bigger fibres escape from the jute processing in the latter sections.

d) The percent-fractions of dust of hygienic importance (below 10 micron size) in the total dust content was found to be increasing from softener to other sections. This should be the case because finer particles predominates in the room air of the latter sections. The quantity of dust retained in the lungs of workers (Brown et al 1960) is more in the initial stages because of the higher overall concentrations and higher percentage of dust fractions there.

6.1.4 Presence of free Silica :

Tests carried out to determine the presence of free silica in the particulates of room air gave results shown in Table 6.3.

Table 6.3 Free Silica content of the total particulates in factory room air

Section	Particulate concentrations (mg/m^3)	Silica content (percent)	mg/m^3
Softener	21.0-56.0	8.31	1.74-5.47
Carding	4.5-78.0	4.23	0.19-3.30
Drawing	2.1-30.6	0.65	0.01-0.20
Spinning	1.5- 5.8	negli.	negligible
Weaving	0.5- 1.6	'	'

The silica content was observed to be maximum in the softener region, which reduced to almost half in carding section and to negligible amounts in other sections. The results indicate that the silica might have been present only as larger particulates and hence might have been removed

by settling in the initial stages. It is also indicative of the property of siliceous matter to form larger particles by flocculation. In that case the silica might have been initially present in smaller particle sizes and later flocculated and quickly removed.

6.1.5 Viable microorganisms in factory room air :

Table 6.4 gives total plate count of microorganisms present in factory room air determined by using nutrient agar and incubated at 35 ± 2°C.

The results are self explanatory. In the sofener and carding sections where the particulate concentrations are maximum, the number of organisms are also very high. However, no linear relation was seend to exist between the number of microorganisms and particulate concentrations. The microorganisms present were also not related to the number of persons occupying the different sections. The implication is that workers are not the source of such microorganisms in the room air. The lower counts in the latter sections indicate that organisms may be attached mainly to bigger particulates which are easily removed.

6.1.6 Pollution hazards in jute mills :

From the results of the studies made, the pollution hazards in jute mills may be summarized as follows :

Table 6.4 Viable microorganisms in factory room air (Nutrient Agar - 35°C)

Section	No. of workers+	Vol. of air sampled (l)	Vol. of dil. water (ml)	Total count Plate I	Plate II	Plate III	av:	No. of organisms per m^3 of air
Softener	4	15	15	75	50	60	61.6	61666
Carding	45	15	15	43	30	41	38.0	38000
Drawing	20	15	15	8	10	11	9.6	9666
Spinning	40	15	15	6	5	4	5.0	5000
Weaving	120	15	15	3	4	3	3.3	3333

+ Persons moving products from section to section are not included

1) The particulate concentration in the working environment of the jute mill studied ranged from 0.5 mg/m^3 to 135 mg/m^3 compared to the permissible limit of 1 mg/m^3 fixed by the American Conference of Governmental Industrial Hygienists (Schilling 1971).

2) The amount of particulates of hygienic importance as percent by weight of total particulates ranged from 0.5 to 4.6, the least value being in softener section and maximum in weaving section. The weight of particulates retained in the lungs of workers was found to be maximum in the carding section followed by softener, drawing, spinning and weaving sections. The maximum value for carding sections was calculated as 1265 µg/8-hr day. The minimum value of [illegible] µg/8-hr day was found in the weaving section. The effect of this may be detrimental to the health of workers.

3) The silica content of particulate concentrations in factory room air was found to be high compared to the threshold limits fixed by American Conference of Industrial Hygienists (1963).

4) The number of microorganisms present in the occupied space, especially the softener and carding sections, were observed to be quite high compared to the value of

$1500/m^3$ in normal occupied rooms as reported by Wright et al (1969). In this connection no section was found to have a value less than the normal value reported.

6.1.7 <u>Effect of pollution on workers - Results of Health Survey:</u>

Interview of workers from various departments of the jute mill to ascertain the effect of particulate pollution gave the following results. Table 6.5 gives the percentages of workers in different sections who have some complaint likely to be connected with particulate pollution. As expected the maximum number of persons were found to be affected in the highly polluted softener and carding sections. Columns 4 and 6 give number of persons with symptoms of Byssinosis (Schilling 1971). Only persons from softener and carding sections have this complaint. Considering the higher concentrations of particulates, the percentages of affected cases are low compared to reported values for cotton mills (Schilling 1971).

Tables 6.6 and 6.7 show relations of age and years of service of workers to effect of pollution. The tables are prepared from data for softener and carding sections only. All age groups were found to be affected by pollution. But percentages of affected cases were more in the upper age levels. Also,

Table 6.5 Effect of particulate pollution on workers in the jute mills

Section	No. of workers interviewed	Number of workers affected				
		Some difficulty	Special difficulty on first day	Cough	Tightness of chess	Other chest symptoms
1.	2.	3.	4.	5.	6.	7.
Softener	20	18(90)+	3(15)	16(80)	3(15)	2(10)
Carding	20	17(85)	3(15)	17(85)	4(20)	2(10)
Drawing	20	5(25)	NIL( )	4(20)	NIL(0)	1(5)
Spinning	20	2(10)	NIL( )	2(10)	NIL(0)	2(10)
Weaving	20	2(10)	NIL( )	1(5)	NIL(0)	NIL(0)

+ Numbers in parentheses show percent prevalence of cases

Table 6.6 Relation of age of workers to effect of pollution

Age Group	Total No. of workers	Number of affected cases	Percent affected
Below 20	3	2	66.6
21 - 30	19	17	89.5
31 - 40	9	8	88.8
41 - 50	7	6	85.7
Above 50	2	2	100.0

Table 6.7 Relation of years of service to effect of pollution

Years of Service	Total No. of workers	Number of affected cases	Percent affected
Less than 5	8	6	75.0
5 - 10	17	15	88.2
11 - 15	6	5	84.2
16 - 20	4	4	100.0
21 - 25	2	2	100.0
Above 25	3	3	100.0

6.2 POLLUTION CONDITIONS IN A COTTON MILL

Table 6.8 shows the concentrations of particulate pollutants in different sections of a cotton mill. It also gives the mean sizes, percent-fraction of dust of hygienic significance and the probable amount of dust that may be deposited in the lungs of workers. Figs. 6.6 and 6.7 give the size distributions of dust and fibre fractions respectively.

Maximum particulate concentration was observed in the bale breaking section followed by old type carding section. The section of new carding machines with local exhaust system showed least particulate pollution. Except this,in all other sections particulate concentrations were observed to be higher than the recommended value (Schilling 1971). The observations showed that only dust poses a health hazard in cotton mills. Fibre, eventhough present, was not found to be hygienically dangerous, being of size much larger than 10 μ.

6.3 POLLUTION CONDITIONS IN A WOOLLEN MILL

The particulate concentrations in a few polluted sections of a woollen mill are given in Table 6.9. It also gives the mean sizes, and percentages of dust and fibre of hygienically important sizes. Figs. 6.8 and 6.9 give the size distribution of dust and fibre fractions of particulate in three sections of the woollen mill.

Table 6.8 Concentrations particle size distributions and hygienic significance of particulates in a cotton mill+

Sections	DUST FRACTION Concentration (mg/m^3)	Geometric µmean size (µ)	standard deviation	%by wt. of size < 10 µ
Bale Breaking	11.4	4.1	2.6	2.6
Opener	6.5	2.5	2.1	11.5
Carding (old type)	8.3	2.4	2.2	35.0
Carding (new type)	0.5	negl.	negl.	negl.
Spinning	5.4	2.2	2.1	41.0
Weaving	3.6	2.1	2.0	57.0

.....continued........ ....

DUST FRACTION %by wt. of size < 6 µ	wt. retained in lungs of workers (µg/day)	FIBRE FRACTION Geometric mean size (µ)	Standard deviation	%by wt. of size < 10 µ
0.65	266.5	16.2	3.8	negl.
3.00	198.0	25.5	5.4	'
14.00	782.0	12.3	4.1	'
negl.	negl.	negl.	negl.	'
17.00	121.0	45.0	4.2	'
28.00	116.3	47.0	4.0	'

+ Measurements are made at breathing level at worker positions.

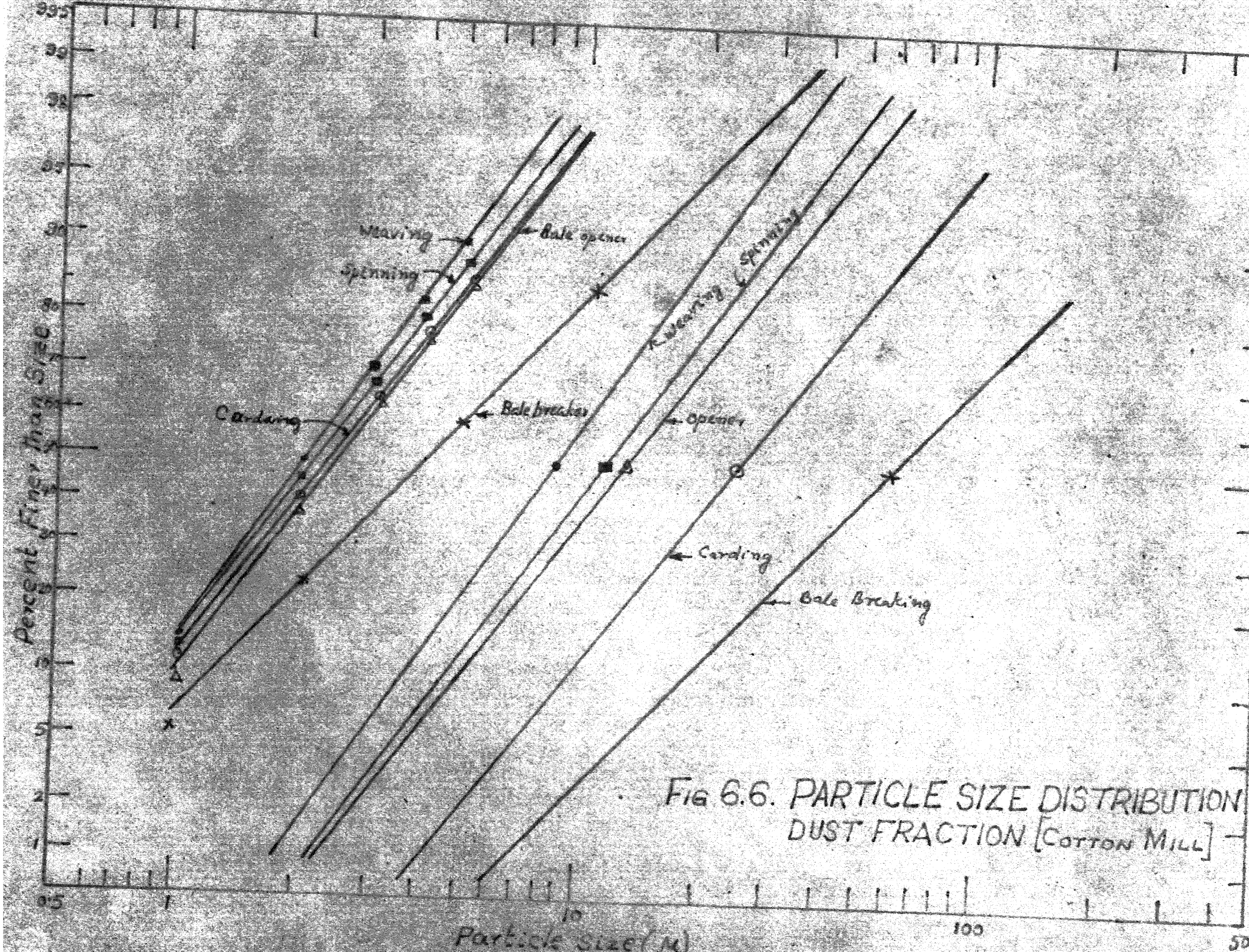


Fig 6.6. PARTICLE SIZE DISTRIBUTION DUST FRACTION [Cotton Mill]

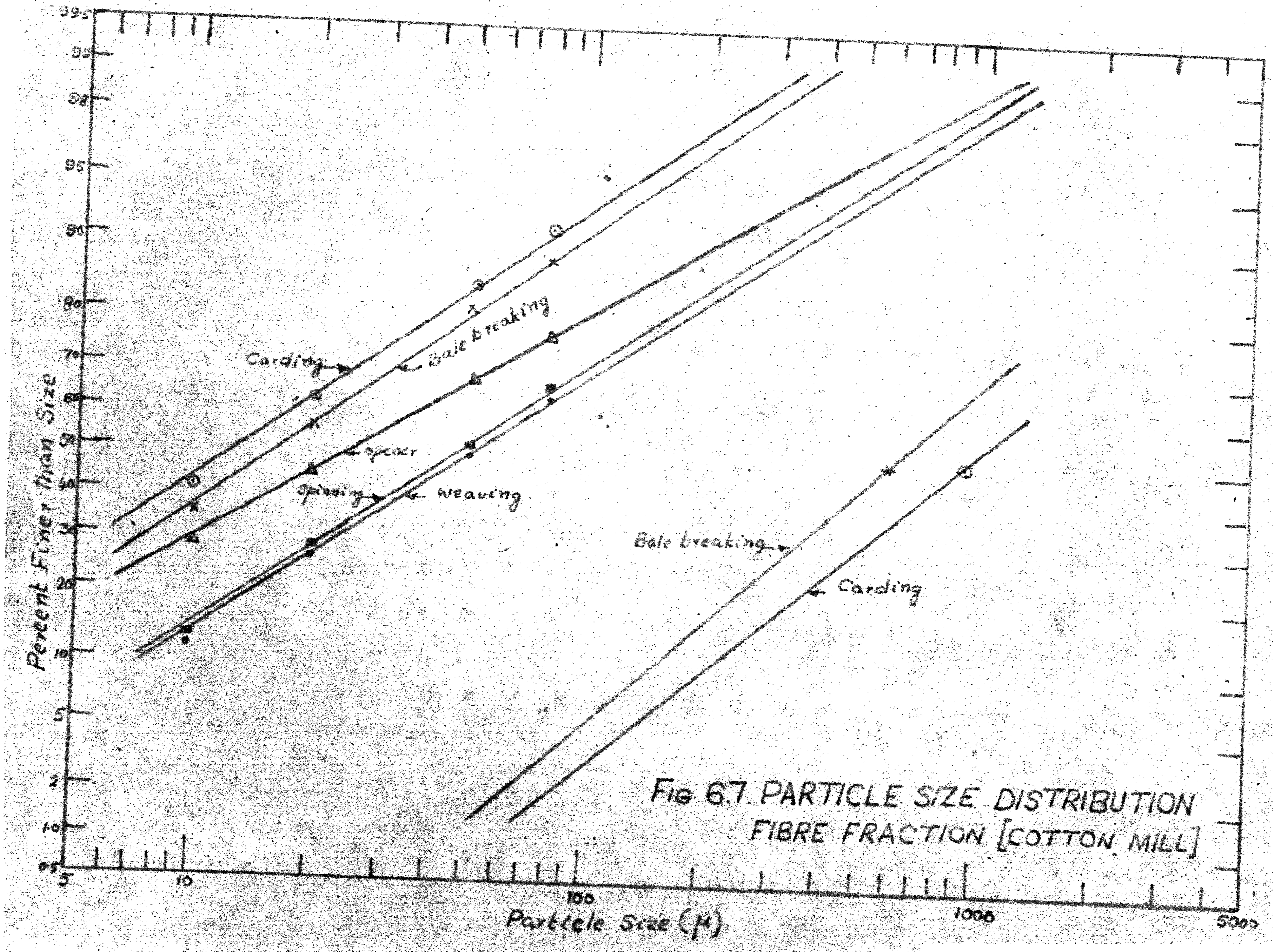


Fig 6.7 PARTICLE SIZE DISTRIBUTION
FIBRE FRACTION [COTTON MILL]

Table 6.9 Details of particulates in various sections of of a woollen mill+

Sections	Concentrations (mg/m^3)	DUST FRACTION Geometric mean size (μ)	Standard deviation	% by wt. of size <10 μ	% by wt. of size <6 μ
Scouring	64.00	4.2	2.8	1.1	0.3
Carding (old type)	5.13	2.4	2.2	10.1	2.6
Carding (new type)	0.22	negl.	negl.	negl.	negl.
Spinning	0.42	2.2	2.0	55.0	26.0

............continued ....

DUST FRACTION wt. retained in lungs of workers (μg/day)	FIBRE FRACTION Geometric mean size (μ)	Standard deviation	Percent by wt. of size < 10 μ
753	31.[illegible]	4.0-	negligible
55	20.0	4.2	"
negl.	negl.	negl.	"
21	45.0	4.6	"

+ Measurements are made at breathing at worker positions.

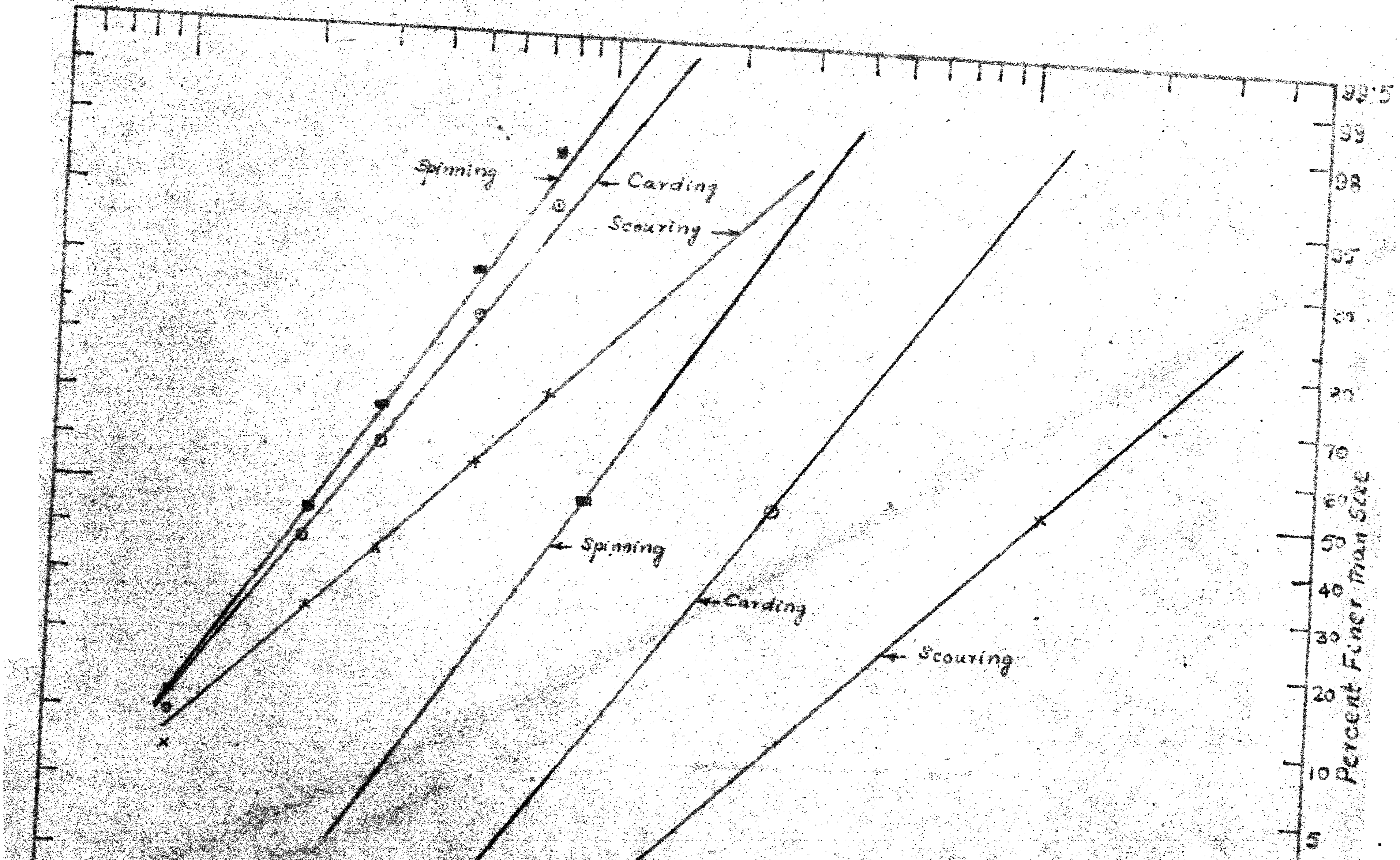


Fig 6.8. PARTICLE SIZE DISTRIBUTION
DUST FRACTION [WOOLLEN MILL]

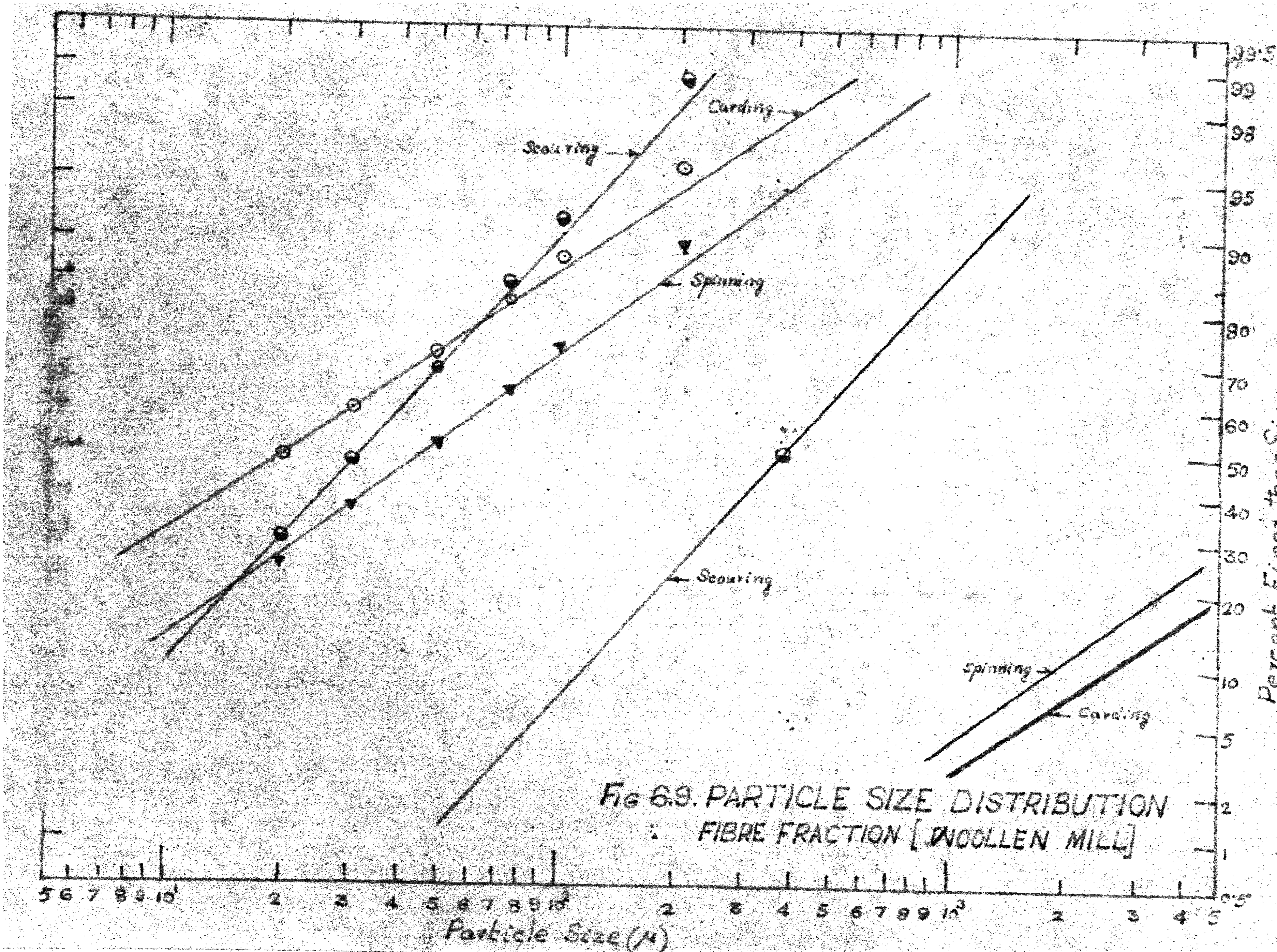


Fig 6.9. PARTICLE SIZE DISTRIBUTION
FIBRE FRACTION [WOOLLEN MILL]

It has been observed that particulate pollution was serious only in the feeding end of the scouring section of the mill where a concentration of 64 mg/m^3 was recorded. In all other sections except the old type carding section (where a concentration of 5.13 mg/m^3 was observed), the concentrations were below the recommended level (Schilling 1971). The reason for the low level concentrations in different sections of woollen mills except the scouring section may be attributed to the efficient removal of dirt and grease by the scouring action.

Health hazard due to the dust pollution was found to be maximum in the scouring section. Hazard due to fibre pollution was found to be negligible in all sections of the mill.

6.4 COMPARISON OF POLLUTIONAL HAZARDS IN THE THREE FIBRE FACTORIES

Fig. 6.10 shows a comparative picture of the pollution conditions in the three types of fibre factories where studies were carried out. The measurements were taken during the month of April, 1975.

The hazards of dust pollution were found to be maximum in the preparing stages in all the three mills. The weight concentration was found to be high in the scouring section of the woollen mill and the same was due to the high percentage of fixed solids in the particulates. The fixed

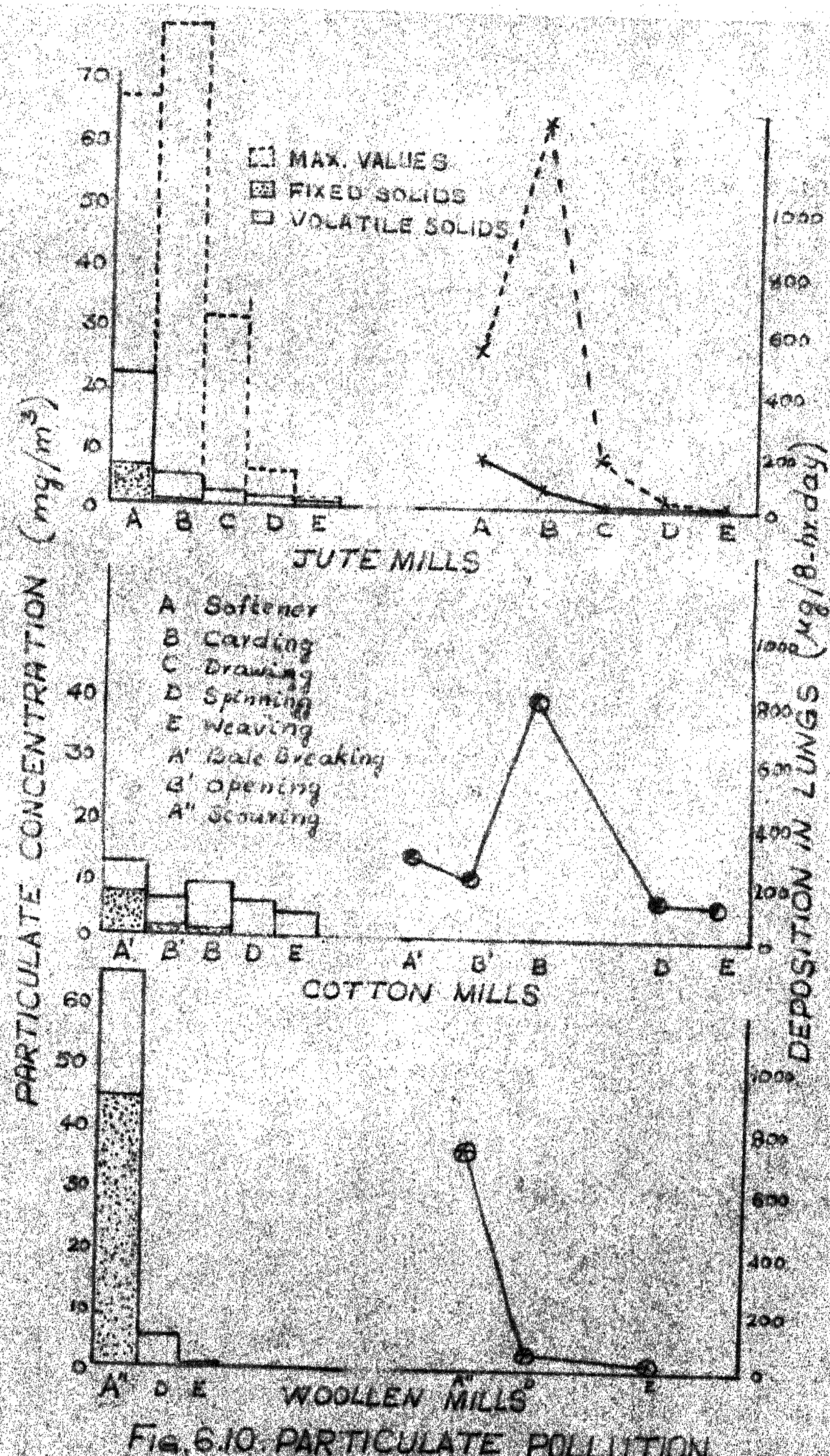


Fig. 6.10. PARTICULATE POLLUTION IN VARIOUS FIBRE FACTORIES AND ITS EFFECT ON WORKERS

solids are also high in the bale breaking section of the cotton mill. But they are removed to a large extent in the first process itself. The cotton mill has some pollution hazard in almost all sections. This may be due to the special nature of cotton from which removal of foreign matter is difficult. Also the fibres are shorter and thinner and have less strength compared to other fibres. The weight of particulates that may, probably, be retained in the lungs of workers are also shown in Fig. 6.10. The jute mills has the least values in this respect. This is mainly due to the cold air supply which has been provided, at the time of study. The maximum values observed during other seasons are shown by dotted lines. In the cotton mill also cold air is supplied. But its effectiveness in reducing particulate pollution in the carding section was found to be lower compared to that in the jute mills. In the woollen mill no cool air supply is provided. The workers are, therefore, additionally subjected to high temperature stresses during the summer months.

Thus the highest health hazard due to particulate pollution will be in the (i) Scouring section of the woollen mills (all the year round), (ii) Bale breaking section and to a lesser extent the carding section in a cotton mills (more hazard during winters due to poorer ventilation) and (iii) a jute mill (once again more hazard during winters).

In all cases improved ventilation whether on a local basis (e.g. a small exhaust fan or a window) or complete air changing will, very significantlly, reduce the particulate concentrations and hence the resulting hazard.

PART B VENTILATION AND POLLUTANT TRANSPORT

6.5 EXISTING VENTILATION CONDITIONS IN THE JUTE MILL

6.5.1 Natural Ventilation

The flow caused by perflation (inflow due to wind action) was found to be 90,000 m^3/hr in January and 150,000 m^3/hr in February. These flows are capable of giving 4.15 and 6.92 air changes per hour. The structural conditions on the western side do not permit flow due to aspiration (outflow due to wind action). The maximum difference in temperature between inside and outside was found to be 30°F during summer as well as winter seasons. The flow caused by this temperature difference was found to be 20,500 m^3/hr in January and 26,300 m^3/hr in February. The total air changes due to the combined effect were calculated to be 4.87 in January and 8.12 in February. These air changes were found to be incapable of reducing particulate pollution to the permissible levels.

6.5.2 Seasonal variation in Total Air flow rates :

Based on measured values of velocities and areas of openings, the total (including both natural and forced ventilation) air flow rates into and out of the factory room during three periods were calculated. In January, the flow was sufficient to give a total of 7.01 air changes per hour. In February, similar calculations yield 10.1 air changes per hour. The increased flow rate was found to be due to increased prevailing winds during this season. (The meteorological data presented in Fig. 6.11 shows the variations in wind speed, temperature, and relative humidity). In April when cool air was supplied into the room, the number of air changes increased to as high as 32.0 per hour.

6.5.3 Relation of particulate concentrations to ventilation :

Fig. 6.12 shows the relation between the number of air changes and particulate concentrations during the periods of study. All curves except 1 and 2 representing the carding and softener sections respectively show similar trends. In carding section where more exhausts are provided there is a marked reduction in particulate concentration with increased air changes indicated by the steepness of the curve throughout its length. In the softener section where no air supply point is provided it was found that increase in total air

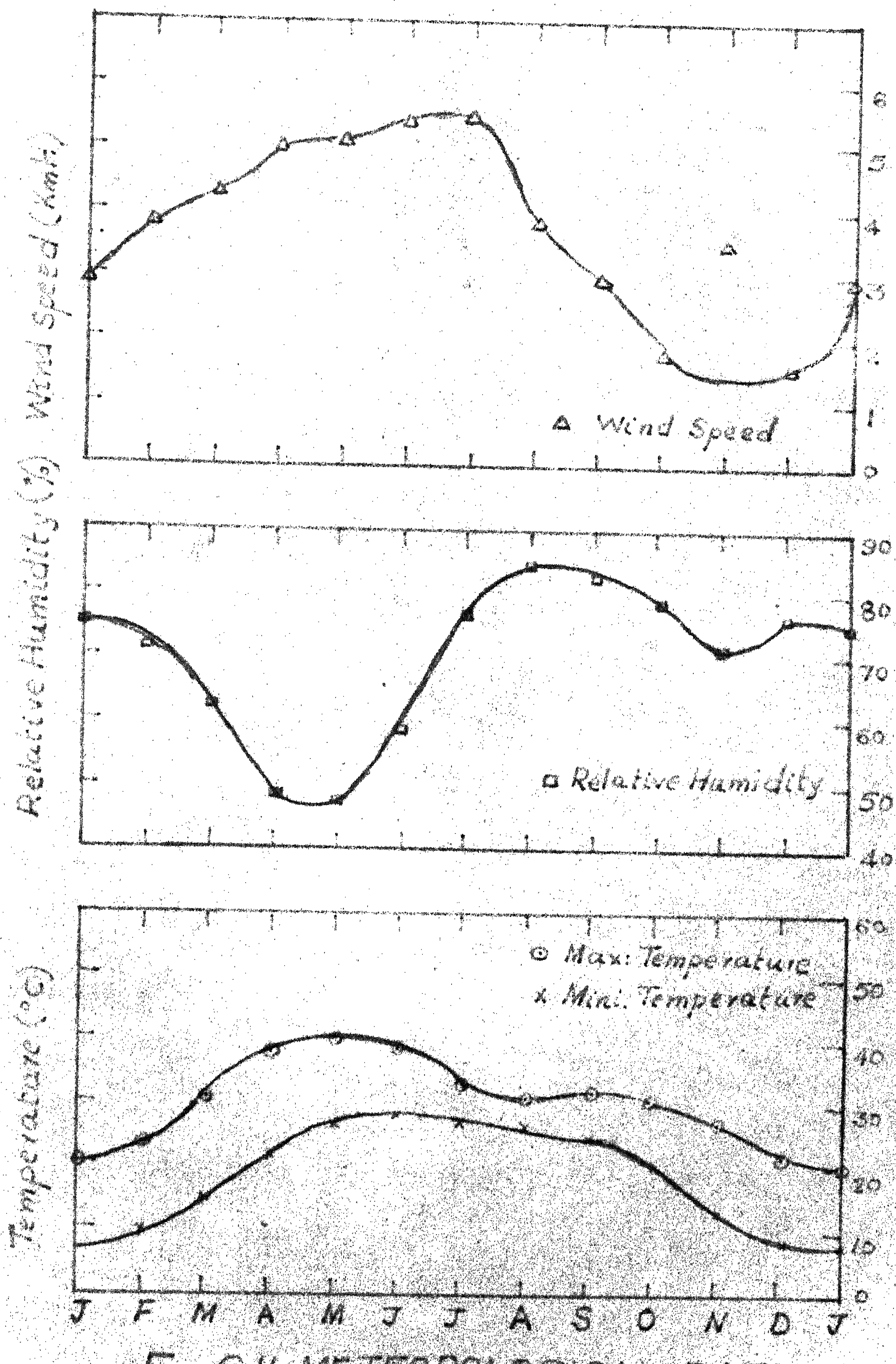


FIG. 6.11. METEOROLOGICAL DATA
AVERAGE VALUES 1971-'75

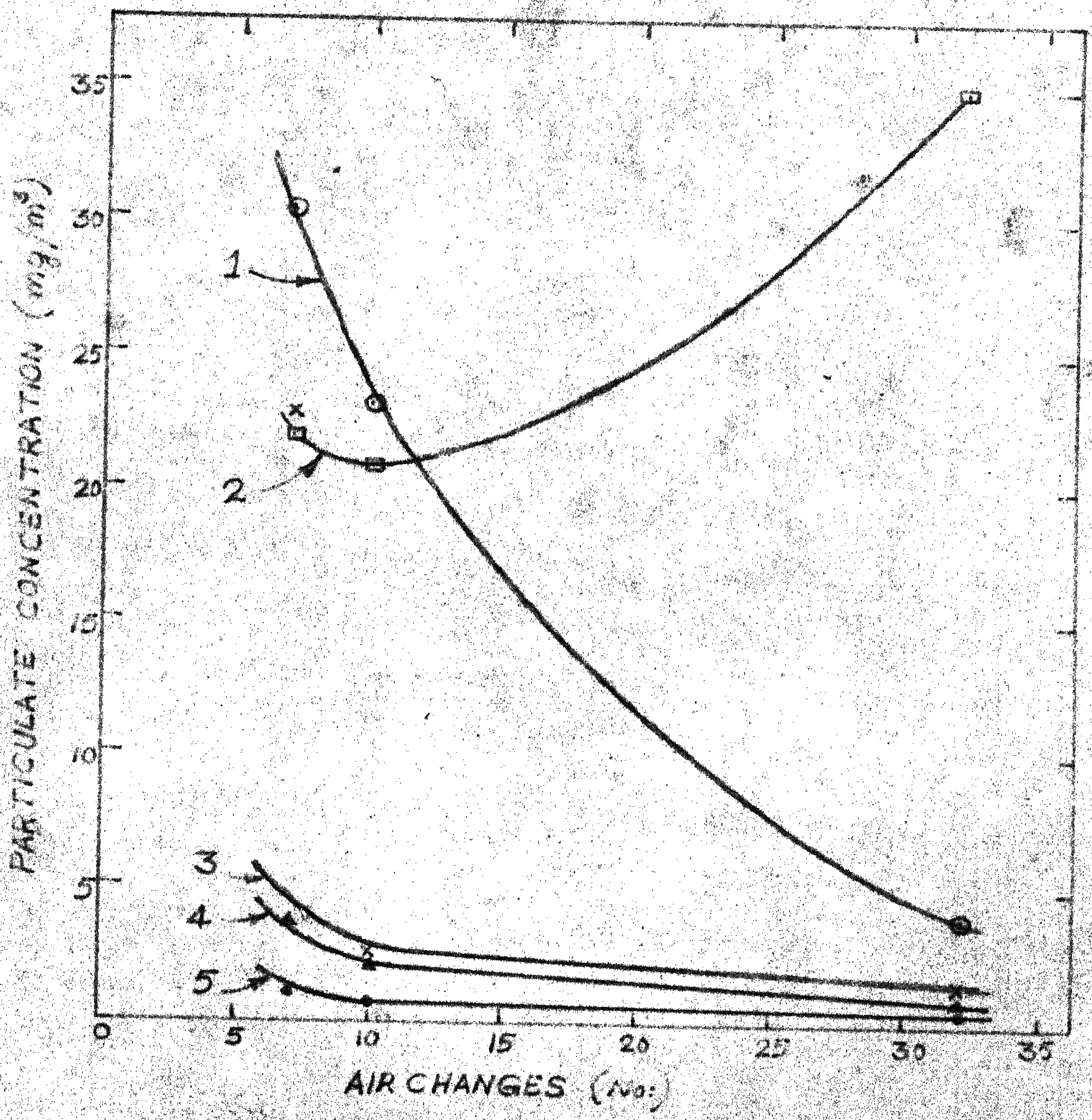


FIG 6.12. RELATION BETWEEN AIR CHANGES AND PARTICULATE CONCENTRATIONS

6.6 VELOCITY DISTRIBUTION INSIDE FACTORY ROOM

6.6.1 Seasonal variations in general air movement :

Figs. 6.13 to 6.15 show the velocity distributions in the factory room during three months when measurements were carried out. In January, the movement was more circulatory in the carding, drawing and weaving sections with linear motion between machines. In February when windows were opened in the carding and drawing sections the movement was more linear from the eastern side to western side. In the upper levels the flow was directed towards the exhaust fans in these sections.

During summer months when cool air was supplied the velocity distribution was as shown in Fig. 6.15. Cool air moved from the sides to the centre where part of it was lowered and part was elevated. At floor level, air moved from centre towards the sides. The direction of flow was observed to be outwards through all the openings due to the increased pressure produced by air supply. In the softener section where no air supply point was provided, the outward flow was found to cause draughts which reduced the efficiency of local exhaust hood over the softener. The particulate concentration in this section was observed to be high due to this reasons.

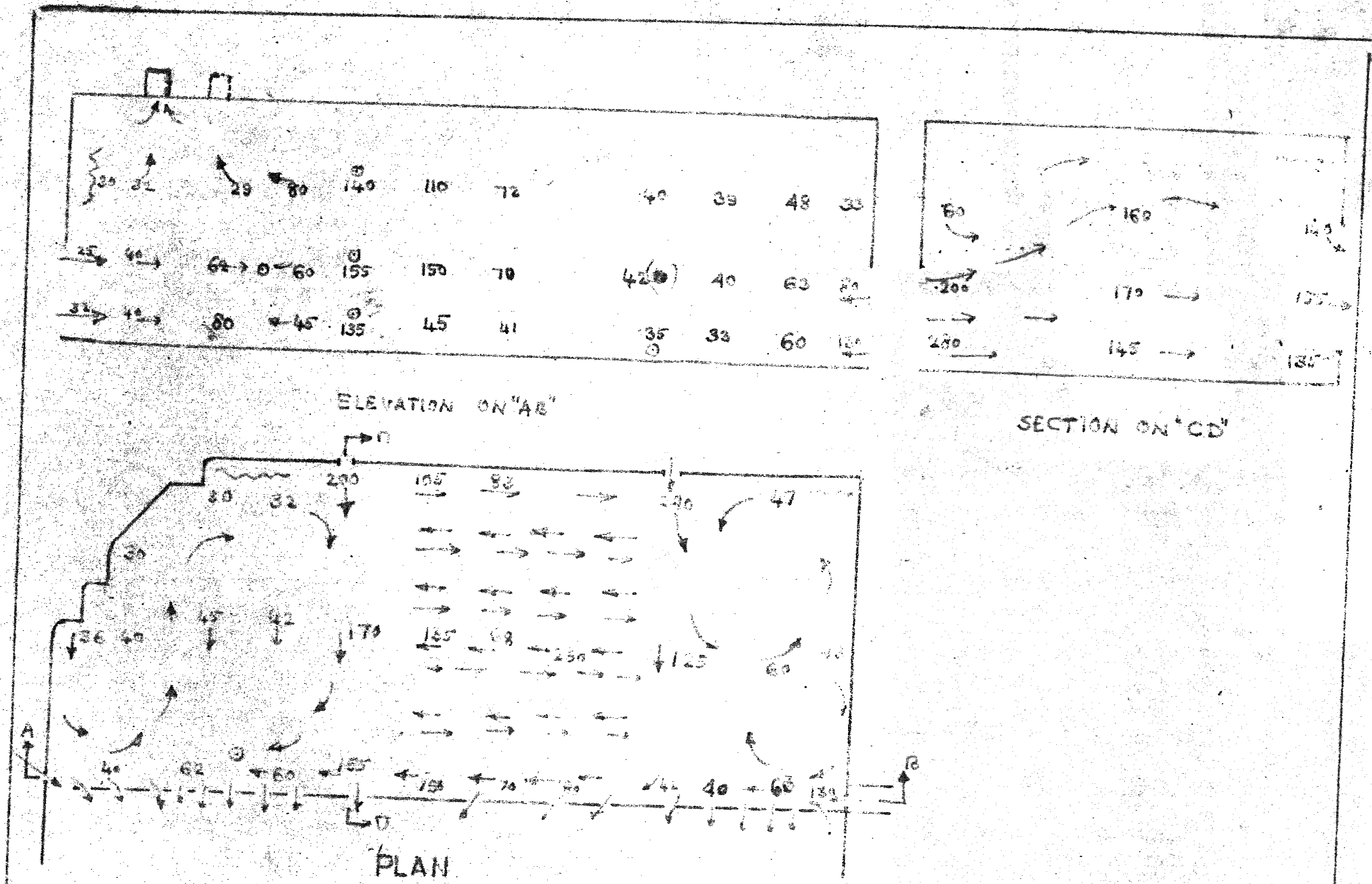


FIG 6.13. VELOCITY DISTRIBUTION
JANUARY (JUTE MILLS)

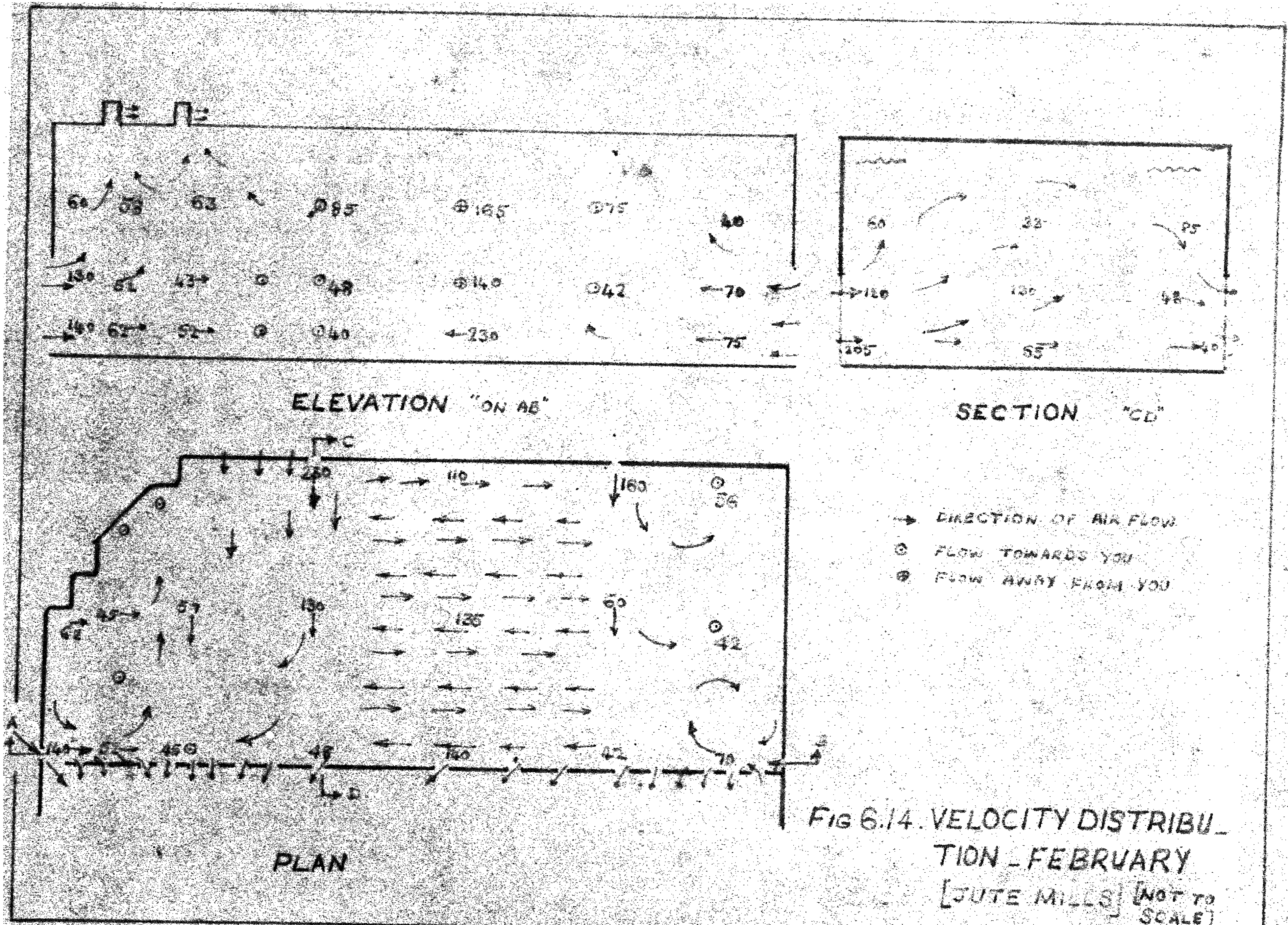


FIG 6.14. VELOCITY DISTRIBUTION - FEBRUARY [JUTE MILLS] [NOT TO SCALE]

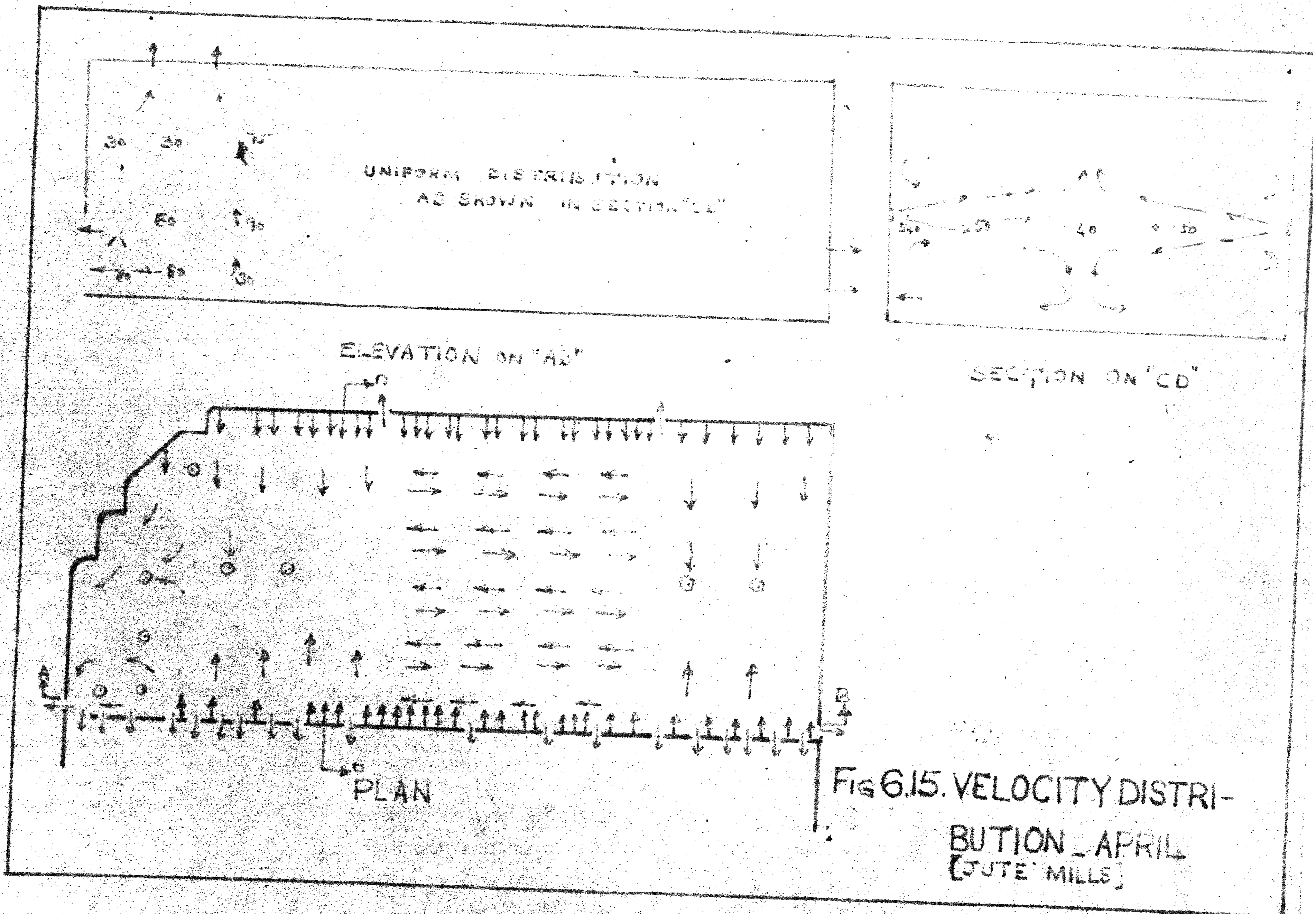


Fig 6.15. VELOCITY DISTRIBUTION _ APRIL
[JUTE MILLS]

6.6.2 Velocity distribution around machinery :

The moving parts of some machines induced air velocities around them. This was mainly noticed in the spinning section of the mill. It was observed that the high speed rotation of the spinning rings produced a velocity of 900 fpm at 8 cm from the ring on the facing side of the machine. The velocity was found to be reduced to 50 fpm in a distance of 60 cms. On the rear side of the machines the velocities observed were around 50 fpm. In no other section the movement of machine parts was found to induce velocities above 50 fpm at a distance of 10 cm from the machine, where it was possible to do measurements.

6.6.3 Velocity distribution in air stream of supply inlets :

Measured values of the centre line velocities of air inlets provided on the side walls are shown in Fig. 6.16. The velocity distribution shows that it does not fully agree with the equation for free stream jet (Schlichting 1958), $\frac{U_{cl}}{U_o} = \frac{K}{x}$, where K is a constant. The reason for the same may be the obstructions caused by machinery and the effect of floor, making the jet not absolutely free stream.

6.7 TEMPERATURE AND HUMIDITY CHANGES IN THE FACTORY ROOM

Table 6.10 gives the temperature and relative humidity in the factory room during the three periods of measurements.

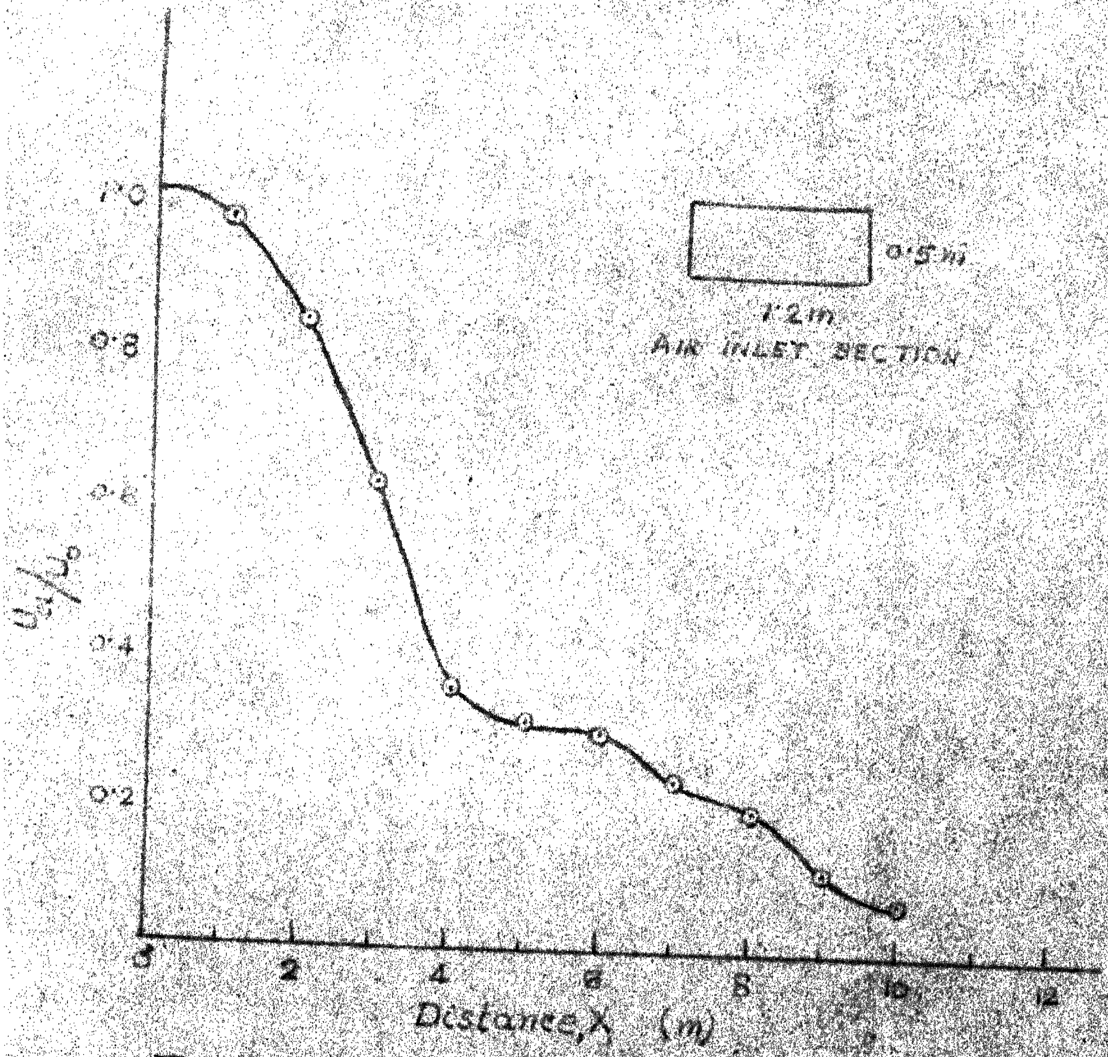


FIG 6.16. VELOCITY DISTRIBUTION AT INLETS

Table 6.10 Temperature and relative humidity in factory room and outside

Section		Temperature (°F)			Relative humidity (%)		
		Jan	Feb	Apr	Jan	Feb	Apr
Softener		73.0	75.0	82.0	64.5	73.5	65.5
Carding		75.0	73.0	79.0	66.0	73.5	73.5
Drawing		77.5	76.5	80.0	63.4	76.2	76.0
Spinning		79.5	81.0	82.0	70.5	76.3	80.0
Weaving		74.5	77.5	83.0	61.5	69.0	69.5
Outside	Max.	67.5	7[illegible].1	111.3	82.5	73.5	49.0
	Min.	45.3	[illegible]3	70.7			

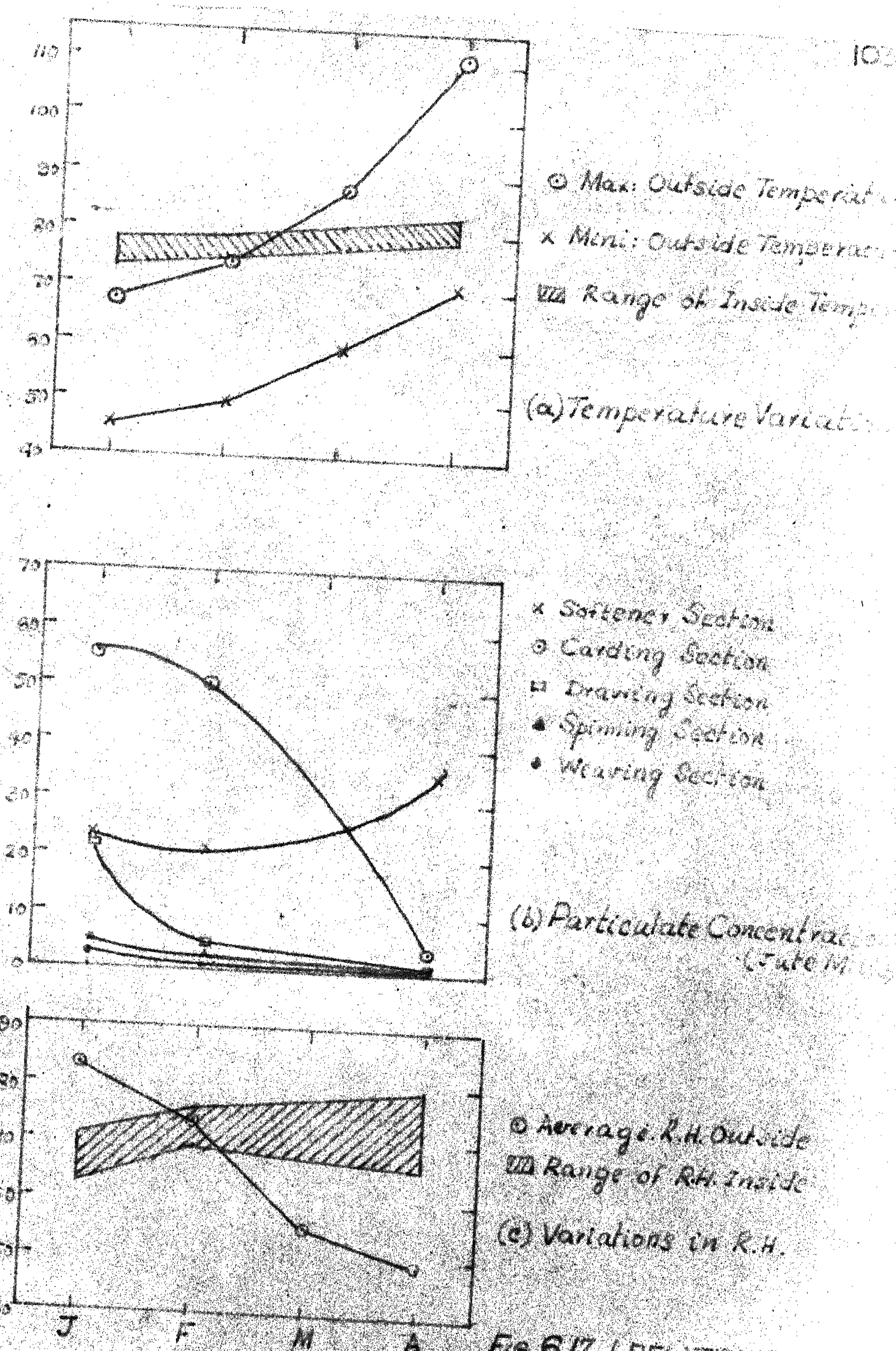
The temperature inside the room showed a maximum rise of 8.5°F during the period of study. It was found to increase with height. The observed difference between floor level and ceiling temperatures ranged from 2 to 5°F. The difference in temperature between the inside and outside of the room was found to be 30°F below the room temperature during January and 30°F above the room temperature during April. Relative humidity inside the room ranged from 60 to 75 percent whereas it ranged from

82.5 to 49 percent. outside. The narrow ranges of temperature and relative humidity inside the room are due to their artificial control.

6.7.1 Relation of particulate concentrations to temperature and relative humidity

Fig. 6.17 gives a comparison between the variations in temperature, relative humidity and particulate concentrations inside the room. When the difference in temperature between inside and outside is maximum, there should be more airflow and hence more air changes and lower concentrations. But the concentrations were found to be lower only in summer when air was admitted into the room mechanically. In winter, when temperature difference was of the same order as in summer the concentrations recorded were high. These indicate that the flow caused by temperature difference is not sufficient to reduce particulate pollution.

An increase in relative humidity should decrease the particulate concentration because of lower production and higher removal. This condition was found to exist between January and February when relative humidity increased and concentrations decreased. But in April when the relative humidity decreased, the concentrations decreased further in all sections except the softener section. These findings



Months of observations

Fig 6.17. / RELATION BET
TEMPERATURE,
RELATIVE HUMI
PARTICULATE CO
TRATION

show that there is no direct relation between temperature and relative humidity variations with change of particulate concentration. Other factors are influencing the particulate concentrations more than temperature and relative humidity.

6.8 PARTICULATE PRODUCTION

Table 6.11 gives a complete picture of the particulate production and transport in the jute mill during February. Particulates produced by various machines were determined by assuming equilibrium condition when production equals transport and settling.

The particulate production was found to be decreasing as we proceed from softener to other machines. This is expectable because the initial processes remove dust and short fibres to the maximum extent. In the drawing section the jute is combed and drawn by the machines. The particulate production is less as the process is very slow. The increase in production in the spinning section is due to the high speed of revolution of the spinning rings and the resulting high velocities. Any foreign matter or short fibres in the thread will be thrown away by this speed. The production in the weaving section is low because very little dust and short fibres will be left on the jute handled in this section.

Table 6.11 Particulate production and transport

	Particulars	SECTIONS					
		Softener	Carding: Braker Cards	Carding: Finisher Cards	Drawing	Spinning	Weaving
T R A N S P O R T	Flux IN(-)	0	340	5900	2585	150	450
	OUT(+)	340	5900	2122	150	913	0
	NET	+ 340	+ 5560	- 3778	- 2435	+ 763	- 450
	Settling(g/hr)	320	2452	4133	2425	107	618
	Exhaust (g/hr)	102	795	175	NIL	NIL	NIL
	Escape through doors (g/hr)	150	250	650	90	150	220
P R O D U C T I O N	Production(g/hr)	912	9055	1180	80	1020	388
	No. of machines	1	8	10	5	40	120
	Production/machine (g/hr)	912	1006	131	16	25.5	3.2

6.9 PARTICULATE TRANSPORT

6.9.1 Size distribution of particulates in the room air :

The size distribution of particulates at various heights in the different sections are given in Figs. 6.18 to 6.22. The percentages by weights of the various fractions of the particulates are given in Table 6.12. The mean sizes of particulates by number dispersed into the factory room was found to be ranging from 2.0 to 5.2 microns. The percentages of the lower size fractions were found to be more towards the latter stages of processing. The mean sizes of particulates are larger in the preparing sections because bigger particulates are removed by the intial processes. The quick settling of the bigger particulates and easier transport of finer ones by the room air to other sections give the reason for the smaller mean sizes in the finishing sections.

6.9.2 Relation of particulate transport to size distribution :

The sizes of particulates are so small that a large portion of them will be easily transported by moving air. According to Hemeon (1963) particulates of sizes less than 20 microns may be considered as lacking any weight or power of independent motion through air. The larger values of flux in different sections as given in Table 6.11 are indicative of this property.

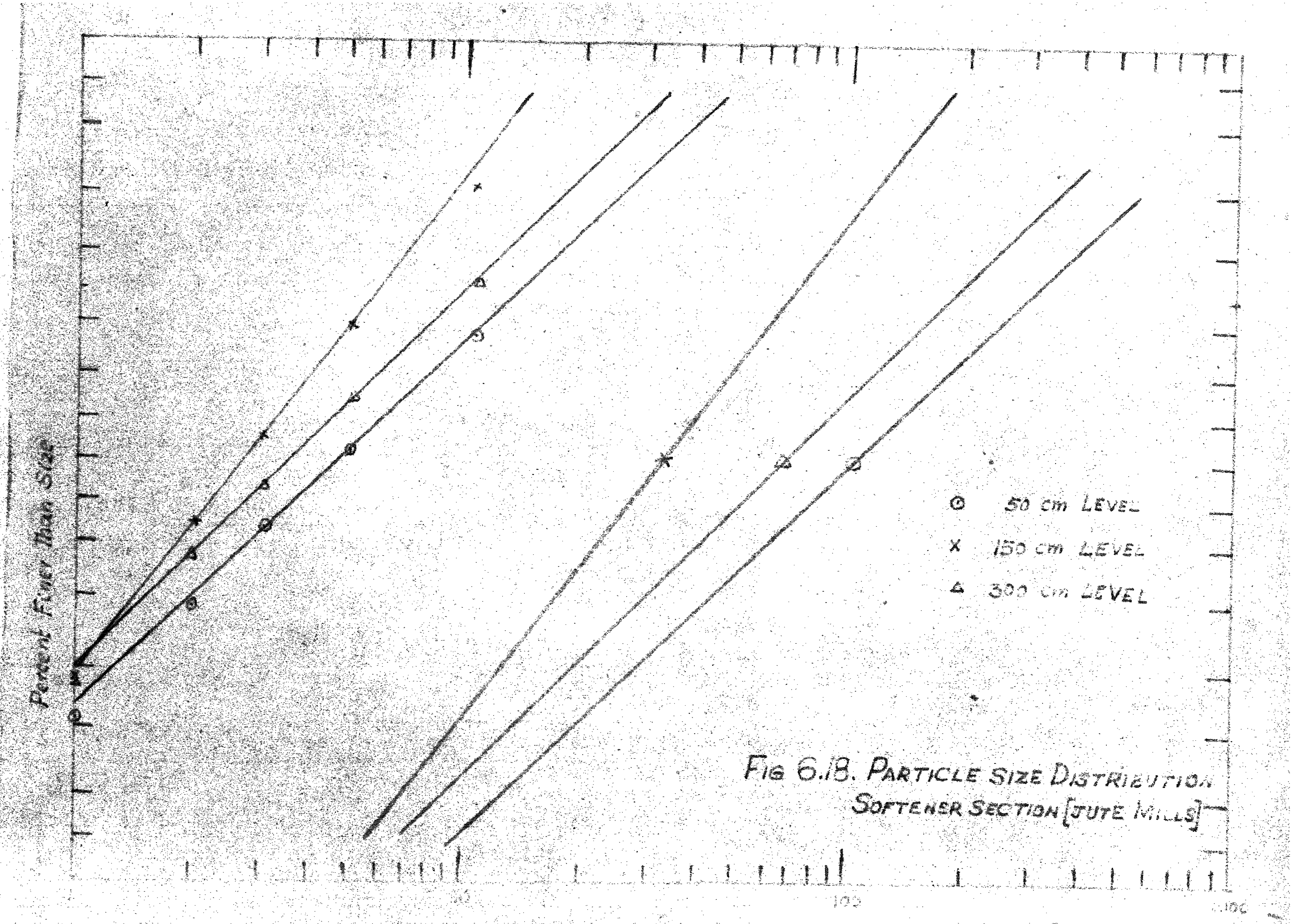


FIG 6.18. PARTICLE SIZE DISTRIBUTION
SOFTENER SECTION [JUTE MILLS]

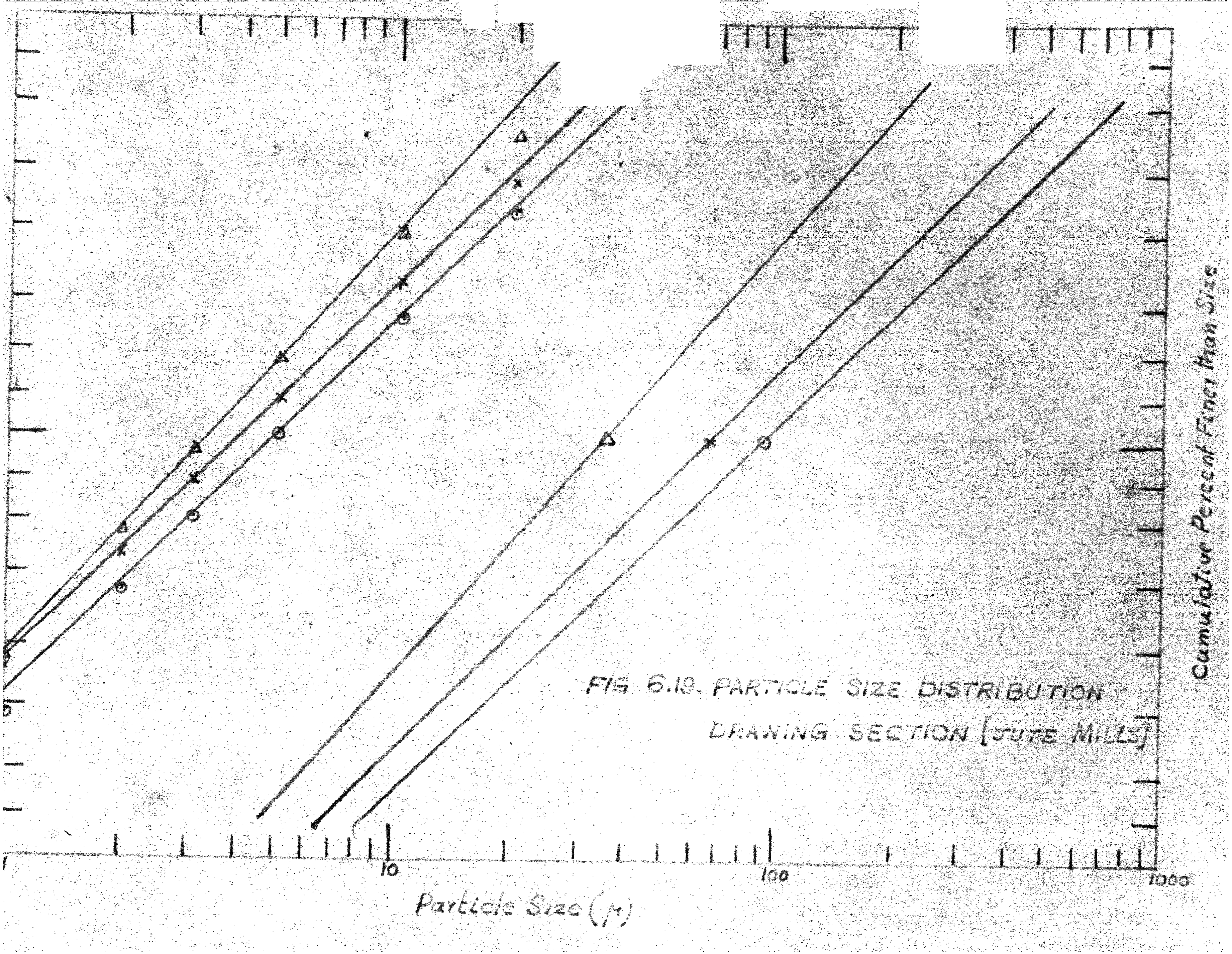


FIG 6.19. PARTICLE SIZE DISTRIBUTION
DRAWING SECTION [JUTE MILLS]

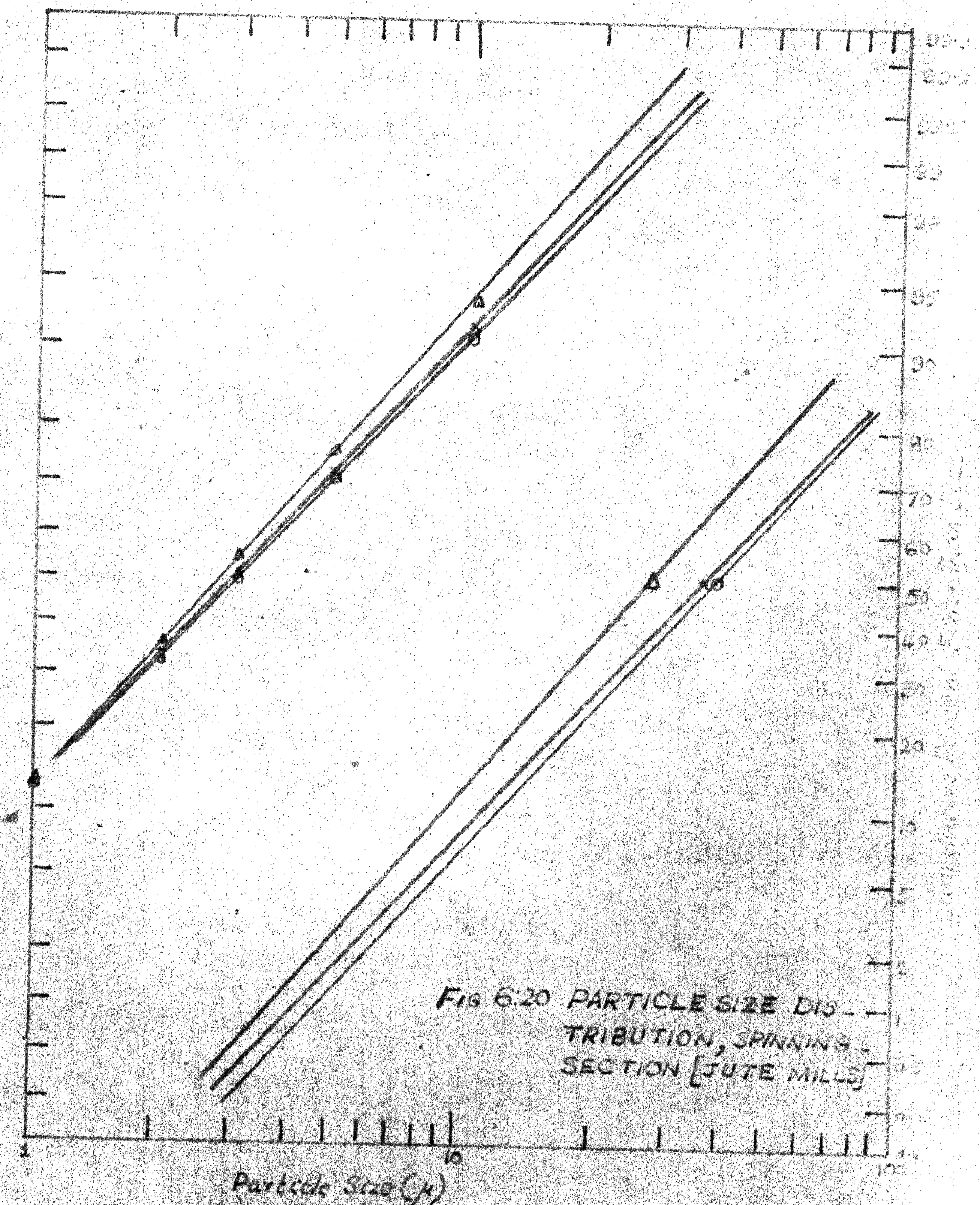


FIG. 6.20 PARTICLE SIZE DISTRIBUTION, SPINNING SECTION [JUTE MILLS]

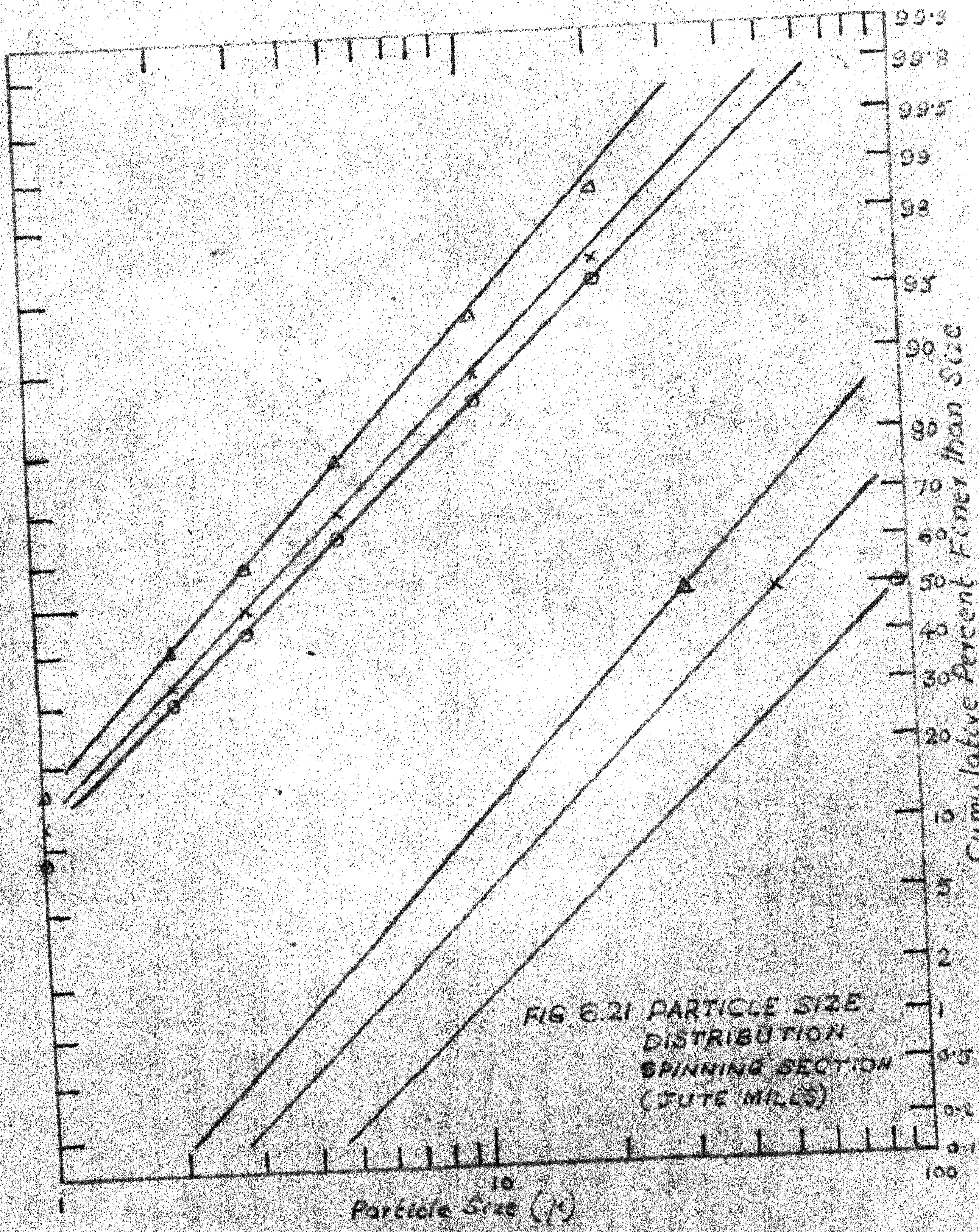


FIG 6.21 PARTICLE SIZE DISTRIBUTION SPINNING SECTION (JUTE MILLS)

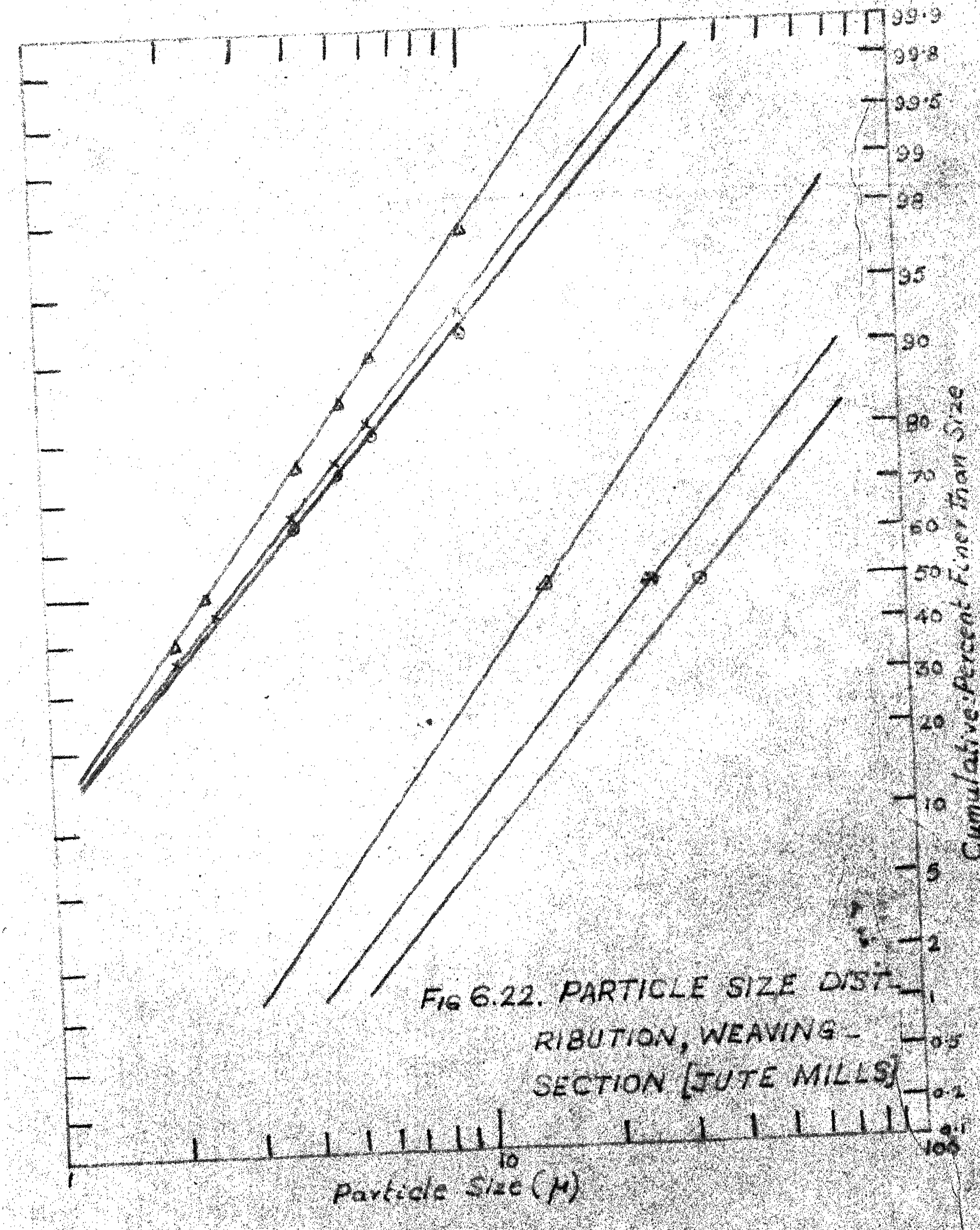


Fig 6.22. PARTICLE SIZE DISTRIBUTION, WEAVING SECTION [JUTE MILLS]

Table 6.12 Percent weights of particulate fractions at different heights in various sections of the jute mill.

Sections		Percent weights of fractions of sizes (μ)								
		<5	5-10	11-20	21-30	31-40	41-50	51-75	76-100	>100
Softener	a+	0.2	0.9	4.4	5.5	7.0	6.0	14.0	10.0	52.0
	b+	0.4	2.2	8.4	9.0	9.0	8.0	17.0	11.0	35.0
	c+	0.6	4.9	19.5	20.0	15.0	10.0	16.0	7.0	7.0
Carding	a	0.2	1.2	5.1	7.0	6.5	7.0	14.0	12.0	47.0
	b	0.4	2.1	8.5	10.0	9.0	8.0	16.0	12.0	34.0
	c	1.1	5.9	18.0	17.0	13.0	10.0	15.5	6.5	13.0
Drawing	a	0.2	1.1	5.2	6.5	7.0	6.9	16.0	11.0	47.0
	b	1.0	4.0	13.0	12.0	11.0	9.0	17.0	9.0	24.0
	c	2.5	9.0	20.0	18.5	12.0	9.0	13.0	6.5	9.5
Spinning	a	1.2	6.0	17.8	15.0	14.0	10.0	14.0	9.0	13.0
	b	1.5	6.7	18.8	16.0	15.0	10.0	13.0	11.0	12.0
	c	2.3	10.2	24.5	19.0	13.0	9.0	10.0	6.5	5.5
Weaving	a	1.1	6.4	19.5	18.0	13.0	10.0	16.0	6.5	9.5
	b	2.2	10.0	25.8	20.0	13.0	8.0	12.0	4.0	5.0
	c	6.2	22.2	38.0	18.0	7.0	4.0	3.0	0.7	0.4

a for 50 cm, b for 150 cm and c for 300 cm height above floor level.

6.9.3 Effect of exhausts on vertical transport of particulates

Comparison of particulate concentrations at two stations in the carding section, one(B) with an exhaust fan on the roof and another (A) with no exhaust fan is given in Table 6.13. It also gives the size distribution of particulates in air at the two stations. The values were obtained from Figs. 6.23 and 6.18. The concentrations in all levels at the station B were found to be much less (one third to one sixth), than those at the station A. This is due to the continuous removal of particulates by the exhaust and their settling on the floor. The percentages of finer fractions of sizes less than 20 μ were found to be more in the upper layers of the area were the exhaust was provided. The effect of exhaust was observed to be less on particulates of size range from 20 - 100 μ. The percent fractions above 100 μ size showed a slight increase in this area.

There should have been a higher percentage of all fractions. But for sizes between 20 and 100 μ the area without exhaust showed higher values. The reasons for this is not fully known. It may be due to the difference in force patterns acting on the particulates of the two stations.

6.9.4 Effect of openings on horizontal transport of particulates

Fig. 6.24 gives the plot of log $\frac{C_o}{C}$ vs L. It gives a set of straight lines indicating exponential relation. The

Table 6.13 Comparison of size distribution of particulates in areas with and without exhaust fans.

Section		concentration (mg/m^3)	Percent fractions by weight of sizes (μ)								
			<5	5-10	11-20	21-30	31-40	41-50	51-75	76-100	>100
Carding	a	78.2	0.2	1.2	5.1	7.0	6.5	7.0	14.0	12.0	47.0
A(without	b	66.5	0.4	2.1	8.5	10.0	9.0	8.0	16.0	12.0	34.0
exhaust)	c	27.2	1.1	5.9	18.0	17.0	13.0	10.0	15.5	6.5	13.0
Carding B(with	a	21.5	0.05	0.5	2.5	3.5	5.0	5.5	13.0	11.0	58.0
exhaust)	b	10.2	0.5	2.8	9.7	10.0	10.0	8.0	17.0	11.0	31.0
	c	10.0	3.0	8.5	18.5	14.0	11.0	8.0	14.0	8.0	15.0

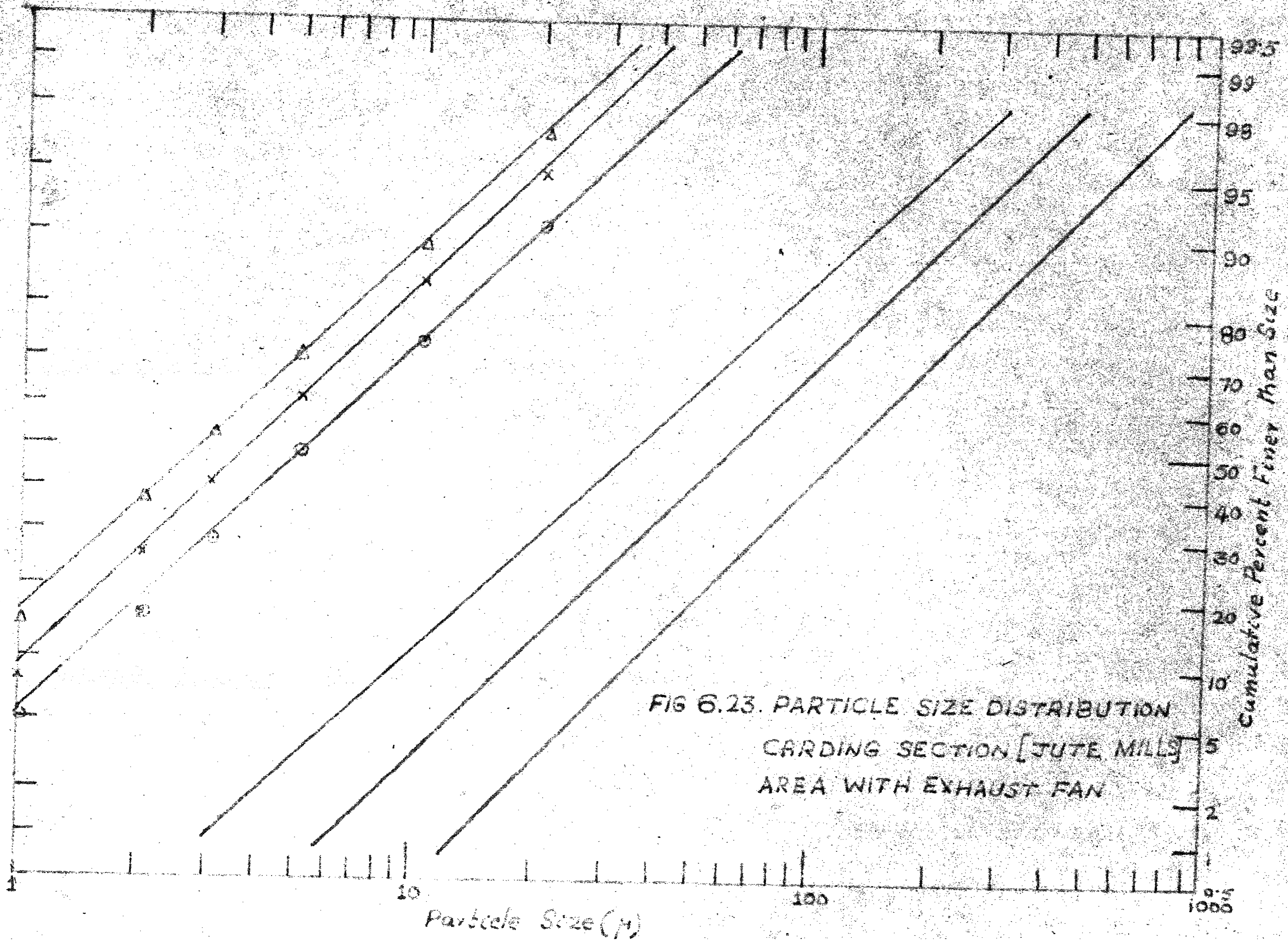


FIG 6.23. PARTICLE SIZE DISTRIBUTION CARDING SECTION [JUTE MILLS] AREA WITH EXHAUST FAN

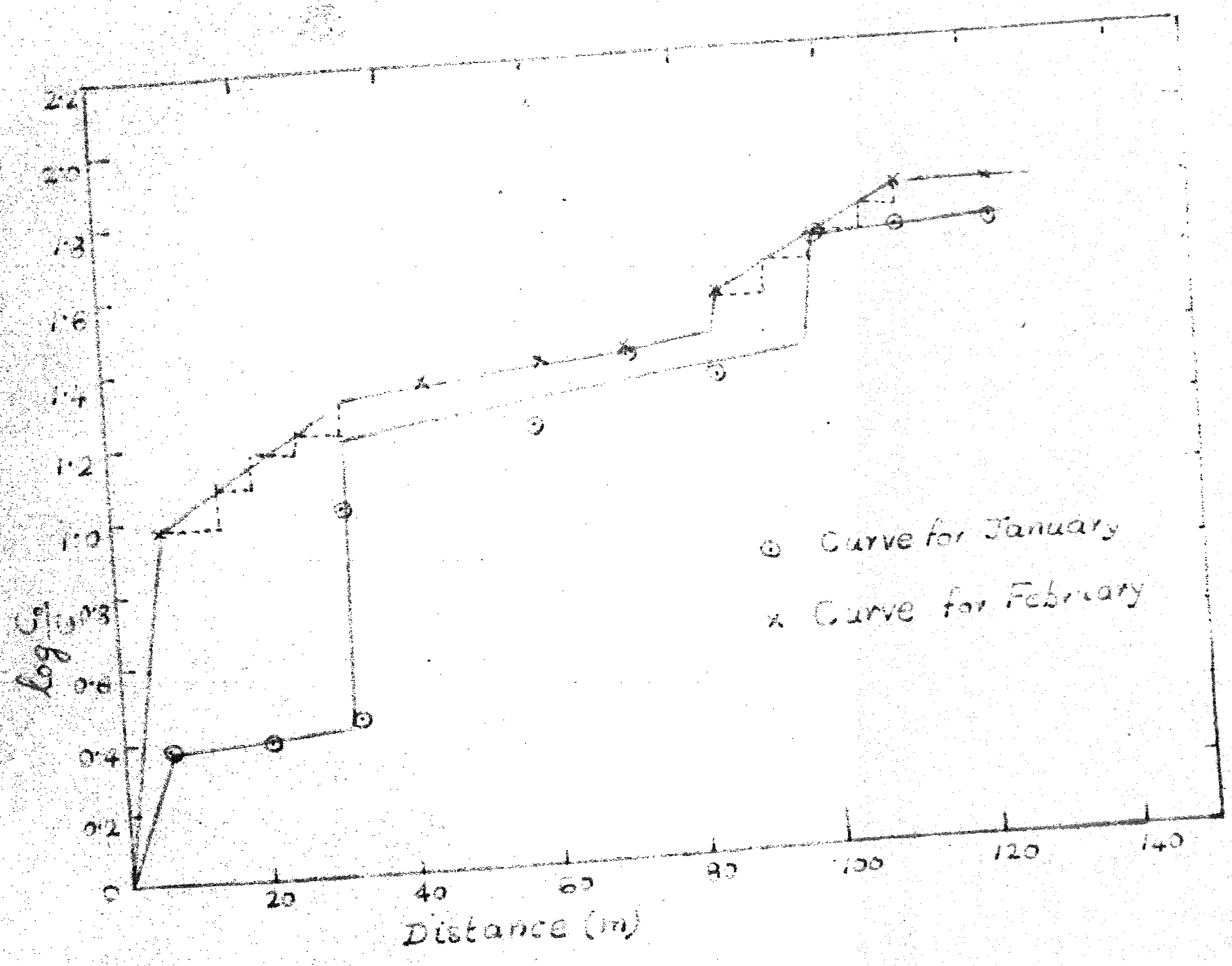


Fig 6.24. Effect of Openings on Horizontal Transport of Particulates

breakes in the graph for January are at distances where doors are provided on the eastern side. The wind blowing in through these doors seems to affect the particulate transport in the room. The doors on the western side were found to have little effect on the particulate transport.

In the curve for February, instead of breaks, inclined lines with steeper slopes could be seen. These lines indicate the combined influence of a number of openings present on the eastern side. If more observations were made between the openings, a step-like pattern (one break for each opening) as shown in the figure by dotted lines would have been resulted.

The value of the coefficient λ, in the equation $\log \frac{C_o}{C} = \lambda L$ was determined for different ~~stretches~~ of the length and ranged from 5.07×10^{-4} cm^{-1} to 9.3×10^{-6} cm^{-1}. for January. For the lengths with windows which were kept closed during January and opened during February, the values changed to 3.76×10^{-5} cm^{-1} and 5.4×10^{-5} cm^{-1} respectively indicating a reduction in the transport. The transport of particulates are, therefore, very much reduced by the cross draughts produced due to inflow of air through openings on windward side.

A similar plot of log $\frac{C_o}{C}$ vs Z, the height, is given in Fig. 6.25. This represents the vertical transport of particulates in the softener sections. The value of λ was found to be 1 x 10^{-4} cm^{-1}, indicating lower transport. The coefficient of eddy diffusion (D_t) in the vertical direction was determined from the equation, $\ln \frac{C}{C_o} = - \frac{v_s \cdot Z}{D_t}$ (Fuchs 1964). The value obtained, 20.9 cm^2/sec, was very high compared to 0.01 to 0.02 cm^2/sec for gases (Foust 1964) This indicates that the transport is due to elution rather than due to diffusion.

6.10 INFERENCES FROM ANALYSIS OF SETTLED PARTICULATES

The plot of cummulative percent by weight of size fractions against sieve openings on a log-probability paper gave special shaped curves as shown in Figs. 6.26 and 6.28. It is obvious that the sample contains dust and fibre and hence the two seperate shapes of plots. (In the previous plots such shapes are not seen because, there, the numbers of dust and fibres were separately determined and plotted).

6.10.1 Difference in Resistance to vertical and horizontal Transport of particulates

Figures 6.26 shows the cummulative percent plot of of size fractions for two points at 2 m height above floor level, one just above the softener and the other at 5 m

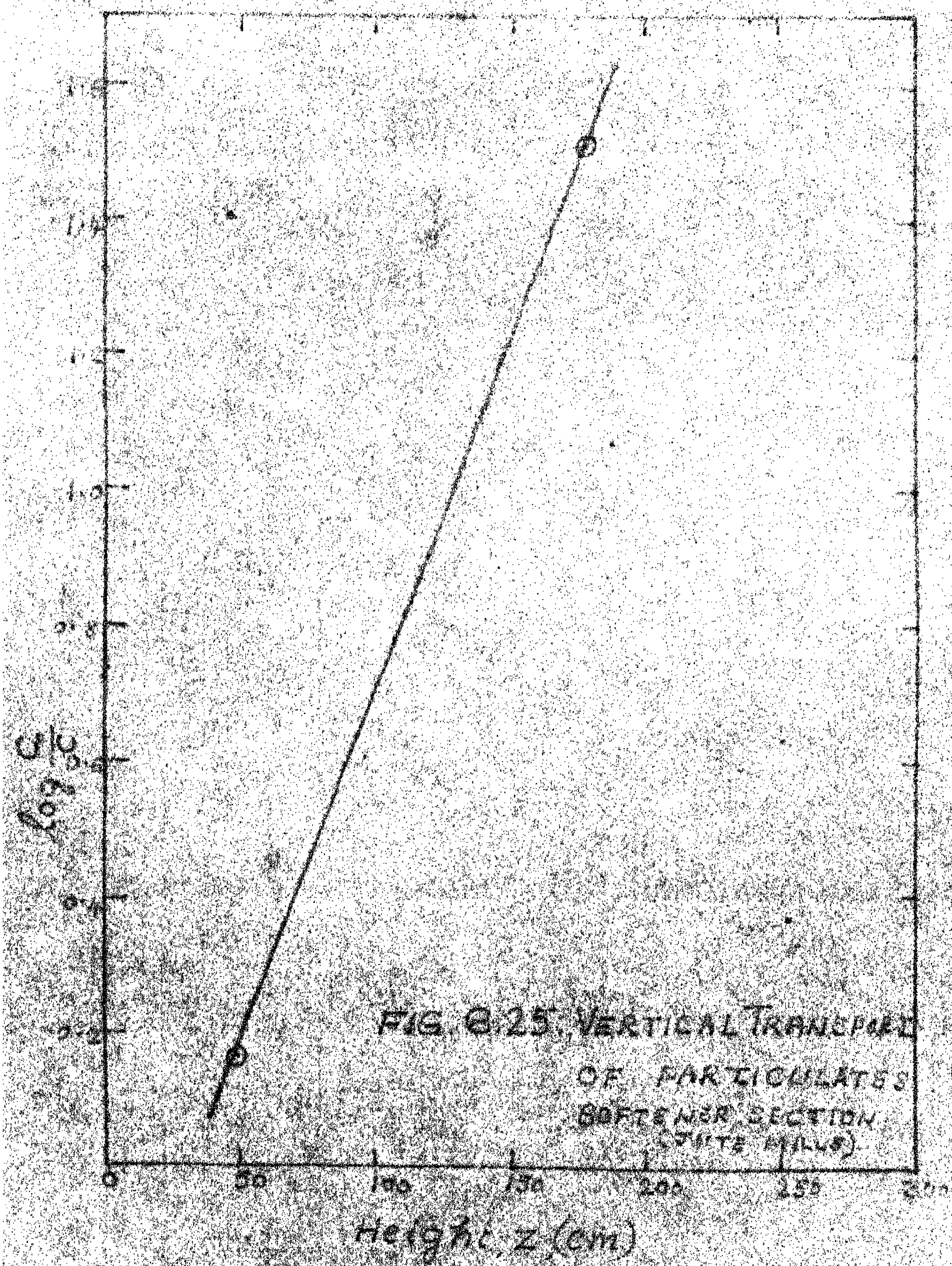


FIG. 8.25, VERTICAL TRANSPORT OF PARTICULATES SOFTENER SECTION (SUITE MILLS)

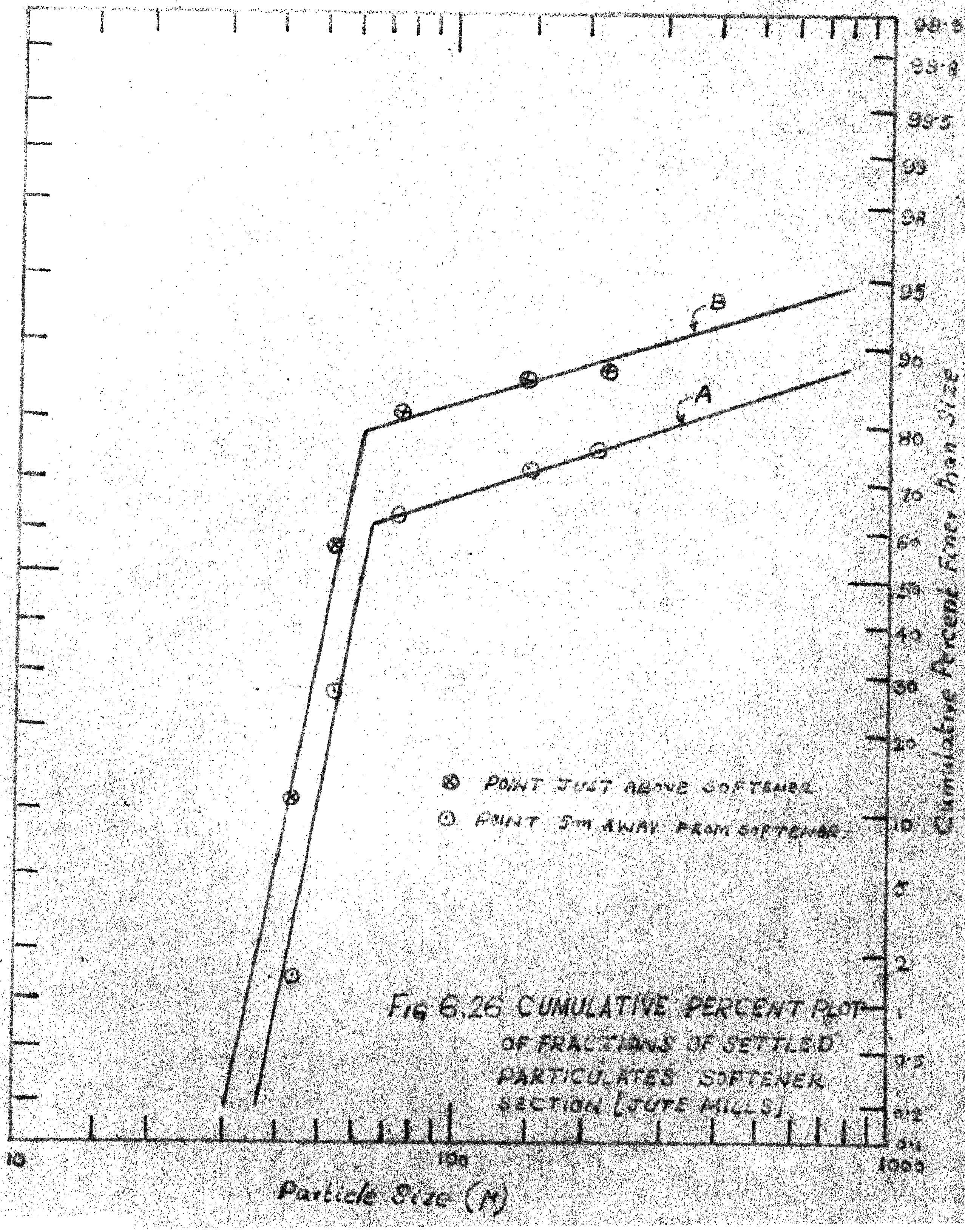


FIG 6.26 CUMULATIVE PERCENT PLOT OF FRACTIONS OF SETTLED PARTICULATES SOFTENER SECTION [JUTE MILLS]

away from it. The cumulative percents of the dust and fibre fractions are given in Fig. 6.27. The details of analysis are presented in Table 6.14. The geometric mean sizes were found to decrease from station 1 to station 2 which should be expected because of the settling of larger fractions during transport. The standard deviation in both cases were observed to be 1.18 for dust. This shows that the sizes of settled particulates come in a very narrow range and this is the maximum size of dust particles present in the total sample. Also, the room air velocity is capable of removing particulates of sizes smaller than this. The mean sizes of fibre fractions were found to be bigger at station 2 compared to station 1. This is quite reasonable from the point of view of the orientation of fibre particles during settling when they take a vertical position. The resistance to transport in the vertical directions will be lower than that in the horizontal directions for fibres. This phenomenon will be a useful guide in deciding the location of exhausts.

Fig. 6.28 and 6.29 show similar plots for samples collected from different heights in the carding section. The details of analysis are given in Table 6.15.

The results show that the mean sizes of settled particulates, generally, decreases with height. This should be

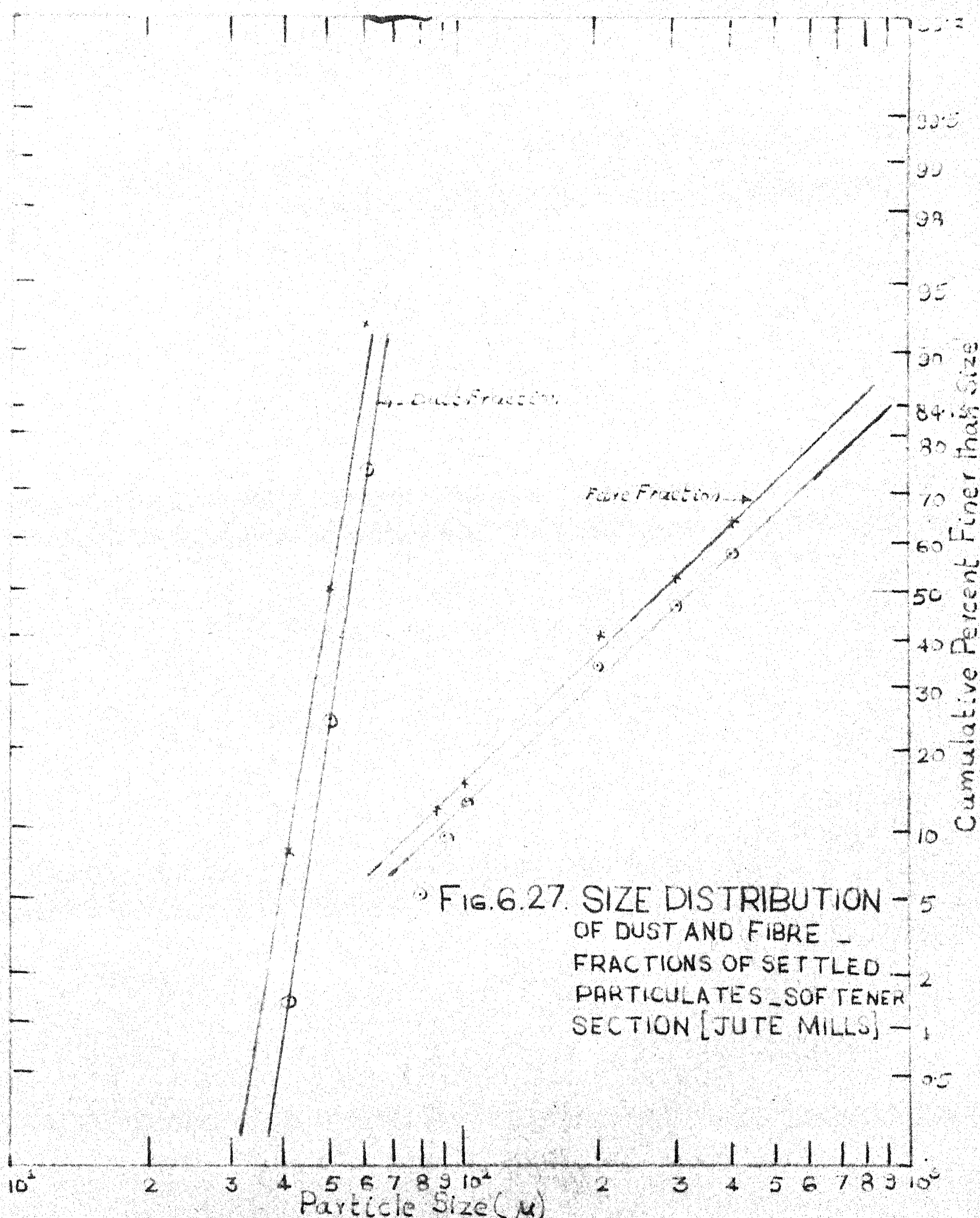


FIG. 6.27. SIZE DISTRIBUTION OF DUST AND FIBRE FRACTIONS OF SETTLED PARTICULATES – SOFTENER SECTION [JUTE MILLS]

Table 6.14 Details of analysis of settled particulates collected from 2 m height above softener section. (Jute Mills)

Station	DUST		FIBRE		Percent fractions in total sample			
	Geometric mean size (μ)	Std. devn.	Geometric mean size (μ)	Std. devn.	<30	31-40	41-50	51-60
Just above softener	56	1.18	220	2.81	0.15	6.5	33.3	34.0
5 m away from softener	50	1.18	275	2.73	0.01	0.9	14.1	31.0

..............contd....

Percent fractions in total sample						
61-70	71-80	81-90	91-100	101-200	201-300	>300
6.0	=1.0	1.0	1.0	5.0	2.5	9.5
16.0	2.0	1.5	1.5	8.0	5.0	20.0

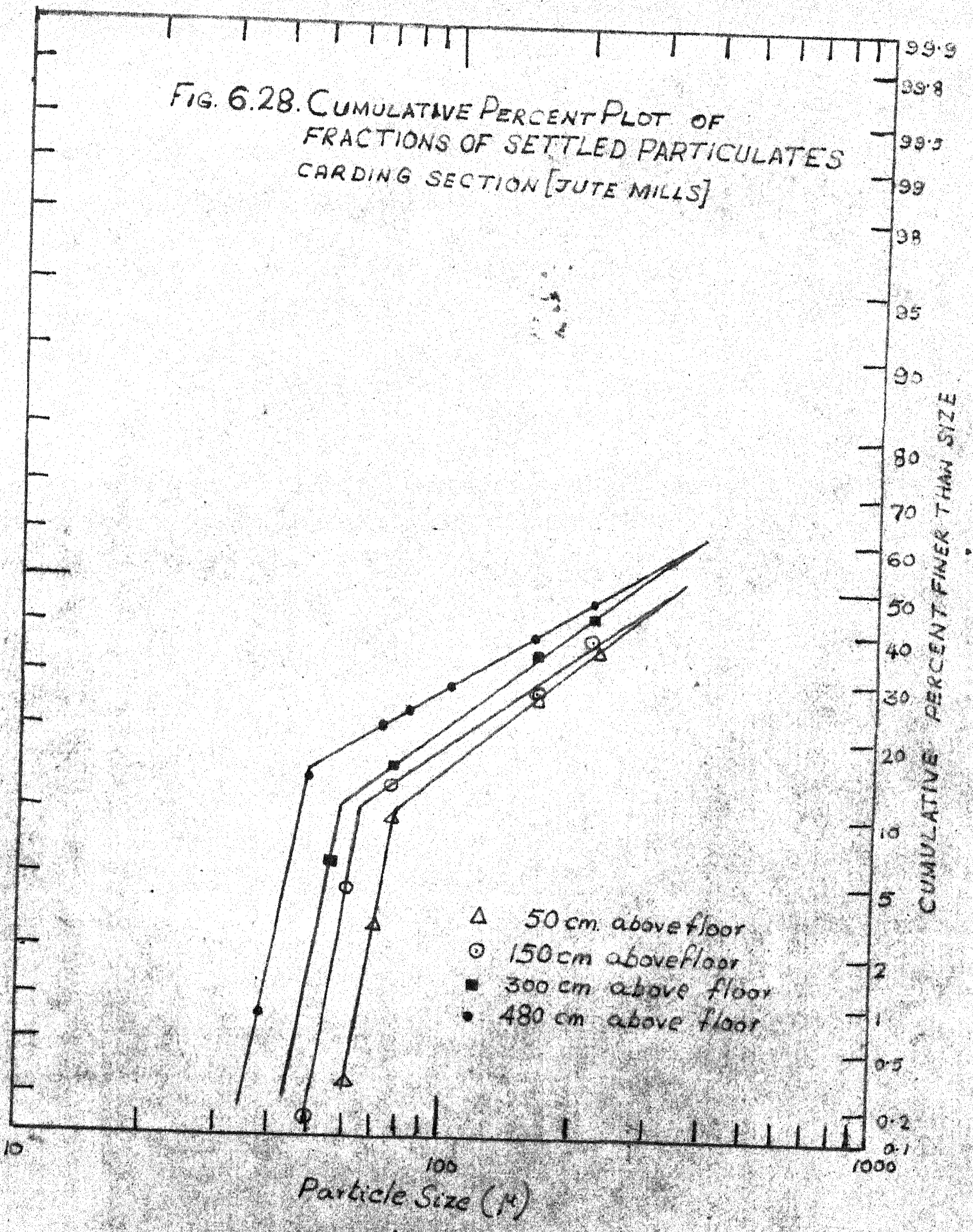


Fig. 6.28. Cumulative Percent Plot of Fractions of Settled Particulates
Carding Section [Jute Mills]
Δ 50 cm. above floor
⊙ 150 cm above floor
■ 300 cm above floor
• 480 cm above floor
99·9
99·8
99·5
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0·5
0·2
0·1
Cumulative Percent Finer Than Size
10
100
1000
Particle Size (μ)

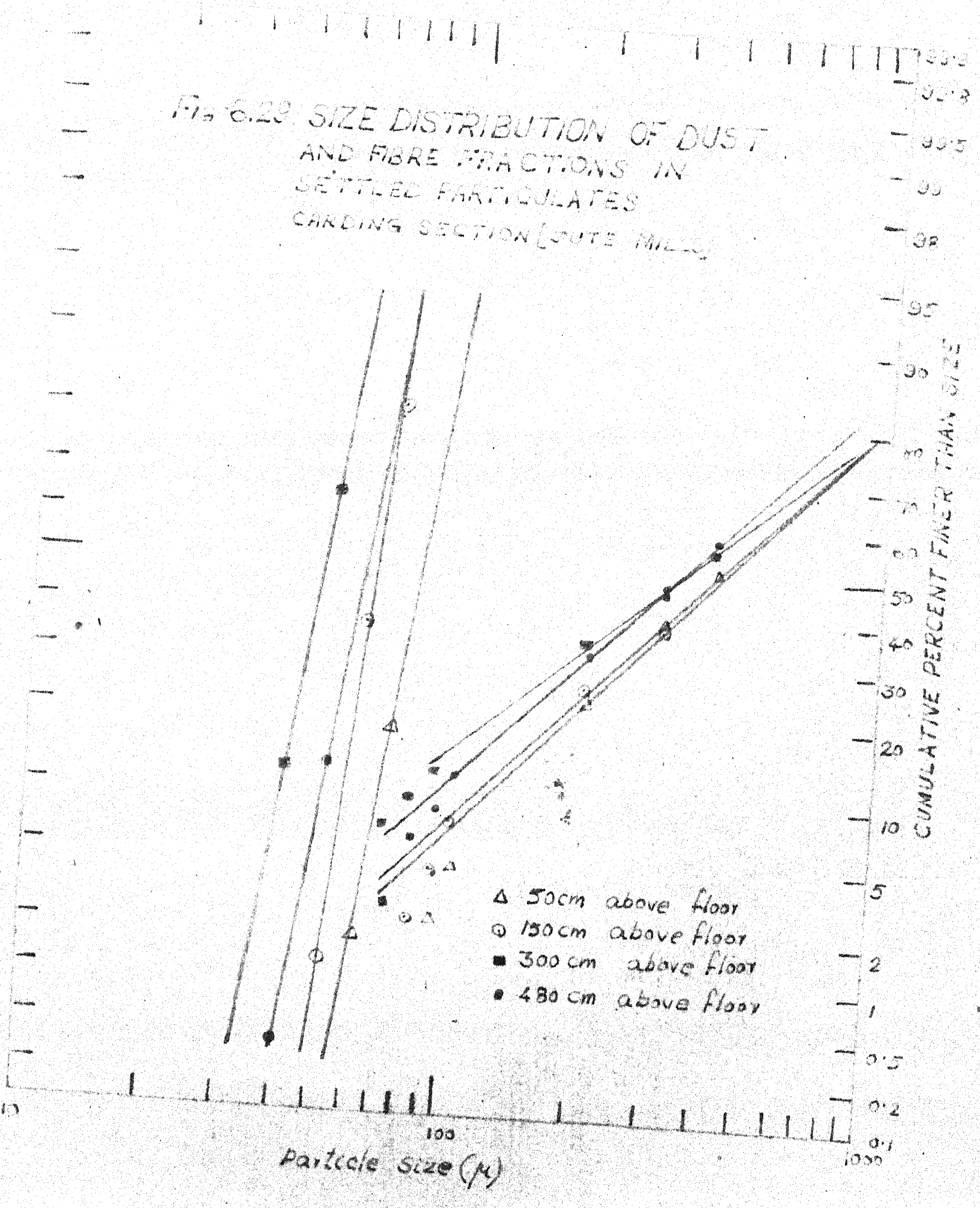


Fig. 6.29 SIZE DISTRIBUTION OF DUST AND FIBRE FRACTIONS IN SETTLED PARTICULATES
CARDING SECTION (JUTE MILL)
△ 50cm above floor
⊙ 150cm above floor
■ 300 cm above floor
● 480 cm above floor
CUMULATIVE PERCENT FINER THAN SIZE
Particle size (μ)
100
1000

Table 6.15 Details of analysis of settled particulates at various heights in the carding section (Junte Mills)

Position	DUST		FIBRE		Per. fractions in total sample			
	Geometric mean size (μ)	Std. deviation	Geometric mean size (μ)	Std. deviation	<30	31-40	41-50	51-60
50 cm above floor	80	1.15	395	2.53	NIL	NIL	0.01	0.19
150 cm "	62	1.15	405	2.69	NIL	NIL	0.15	4.35
300 cm "	47	1.17	330	3.33	0.02	1.78	13.20	3.00
480 cm "	57	1.18	345	2.22	NIL	0.04	1.76	9.50

. . . . contd.

Percent fractions in total sample							
61-70	71-80	81-90	91-100	101-200	201-300	301-400	>400
1.8	9.0	2.0	2.0	19.0	13.0	10.0	43.0
7.5	2.0	2.0	2.5	16.0	10.0	11.0	44.0
3.0	2.0	3.0	2.0	16.0	11.0	7.0	38.0
2.5	3.0	2.0	3.0	18.0	14.0	8.0	38.0

the case because larger particulates are more in the lower layers as they settle easily. In the last stretch an increase in mean size was observed. This is due to the suction effect exerted by the exhaust fans provided in this section. The percent fractions in the total sample also show expected results. The percentages of finer fractions were found to be more at higher levels and those of bigger fractions at lower levels. The deviations from this general pattern are few and can be attributed to the location of source, difference in air velocity and the presence of exhausts on roof.

In general, the ventilation conditions in the factory room showed that natural ventilation could not be depended upon to reduce particulate pollution in the preparing sections of the factory room. The distribution of supply points are not satisfactory, especially in the softener section, Modifications in the present system will improve the ventilation and reduce particulate pollution considerably.

CHAPTER VII

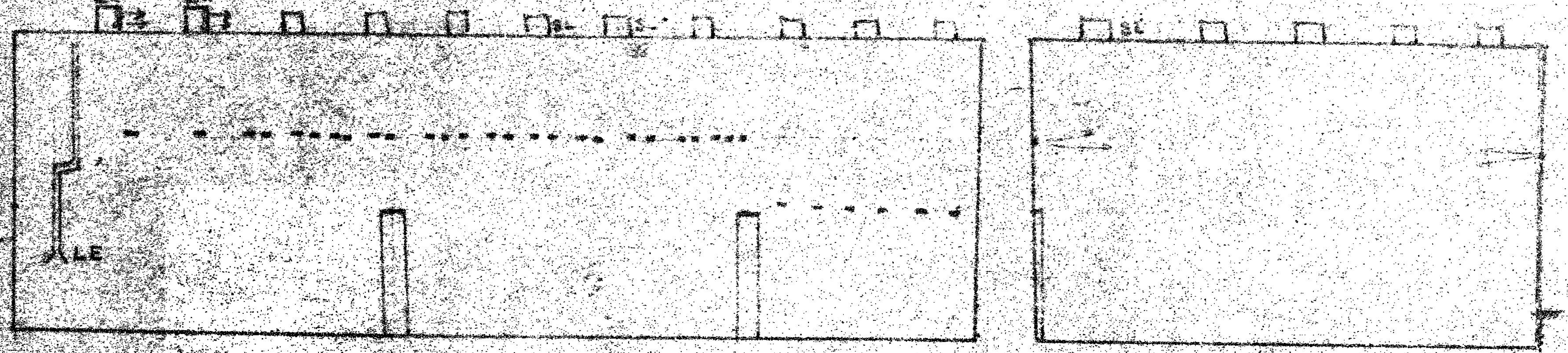
PROPOSAL FOR AN IMPROVED VENTILATION SYSTEM FOR A TYPICAL FIBRE FACTORY

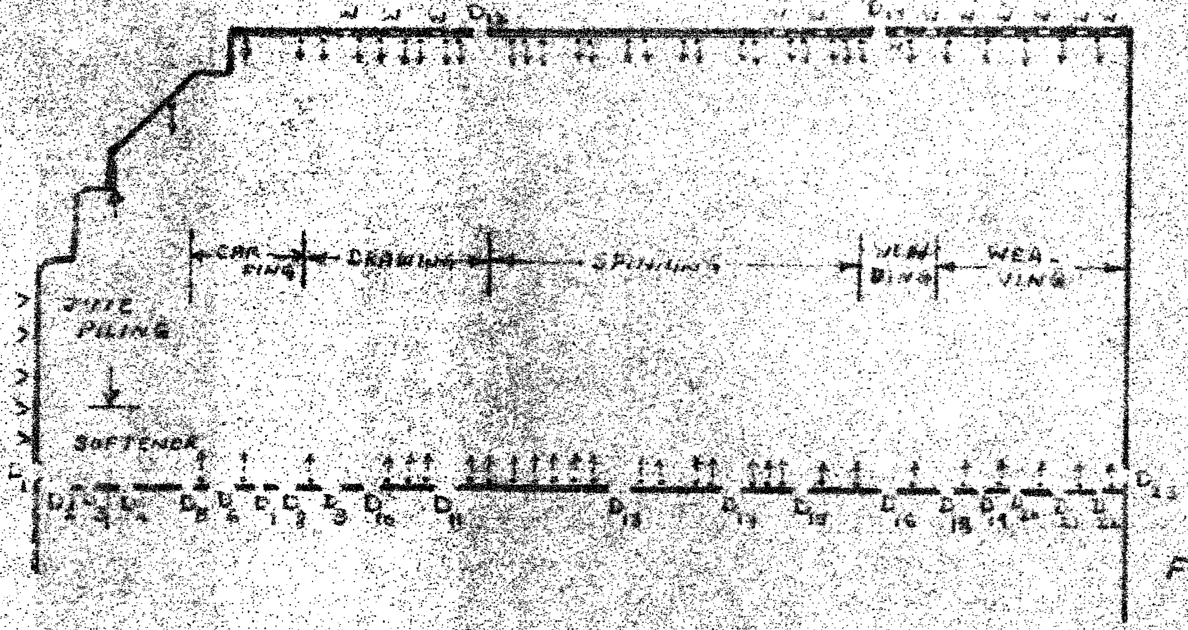
Any system of ventilation intended for reducing pollution should be capable of preventing unnecessary dispersion of contaminants. It should also keep the pollutant concentrations in occupied spaces within permissible limits. The results of the studies carried out have shed some light on the influencing factors, a knowledge of which is essential for the design of a desirable ventilation system. Of the three mills covered by this study, the jute mill seemed to have the most adverse conditions as regards particulate pollution and the discussion in previous chapters clearly reveals that pollutional hazards can be reduced to a minimal if not entirely eliminated by modifications and improvements in the ventilation system. Outlines of a proposal for such modifications are given below which are also expected to indicate directions for other mills.

7.1 EXISTING VENTILATION SYSTEM IN THE JUTE MILL

7.1.1 Details of the Factory Room :

Fig. 7.1 shows details of size, openings and exhausts of the factory room, the ventilation conditions of which were studied in detail. (Table 5.1 gives details





SYMBOL	DESCRIPTION	NUMBER
$D_1 - D_{23}$	DOORS	22
W	WINDOWS	14
V	GLAZED OPENINGS ON WALL	5
SL	SUNLIGHT OPENINGS ON ROOF	11
LE	LOCAL EXHAUST	1
EX	EXHAUST FANS	4
→	AIR SUPPLY POINTS	6

FIG 7.1. EXISTING VENTILATION CONDITIONS [JUTE MILL]

like volume of the room, areas of openings, rate of air extraction, rate of air supply, etc of the room in question.)

7.1.2 Operation schedule :

The operations of exhausts, inlets, outlets and other openings during the year round are given in Table 7.2.

Table 7.1 Operation Schedule for Existing Ventilation System in the Jute Mill

Unit	Period of Operation or of keeping open
Exhaust fans and local exhaust	Throughout the day on all working days
Supply inlets	From April through September depending on outside temperature
Doors on outlet side (West)	Throughout the year
Doors on sides (North and South)	Throughout the day on all working days, Partially covered during winter.
Doors on inlet side (East)	As above (Doors on sides)

7.1.3 Defects in the present system :

Even though exhausts are provided in the softener and carding sections, the particulate concentrations in these sections are above the permissible limit throughout the year. During summer months when cold air is supplied and

concentrations are least in other sections, the particulate concentration in the softener section is still high. These indicate that the ventilation is inadequate and inefficient. The following defects in the present system could be pointed out.

1) <u>Location of local exhaust in the softener section :</u>

The location of the local exhaust hood provided over the softening machine (Fig. 7.2), is not correct in relation to its position with the emulsion (oil-water mixture) supply point. At present, it is provided just after the emulsion supply point. When the moisture content of jute is high, particulate escape from it will be low. So the present location of the hood is at a point where the particulate production is least and is not commensurate with good efficiency.

2) <u>Location of exhaust fans :</u>

In the carding section exhaust fans are so located (Fig. 7.3) that the flow induced by them disperses the particulate produced by the breaker carding machines (major source) into the working environment. The flow pattern should be such that the dust bearing air stream should, as far as possible, not cross the breathing zone of workers.

3) <u>Elevation of exhaust fans :</u>

The capacities of the exhaust fans are low and their present elevations make them incapable of producing the

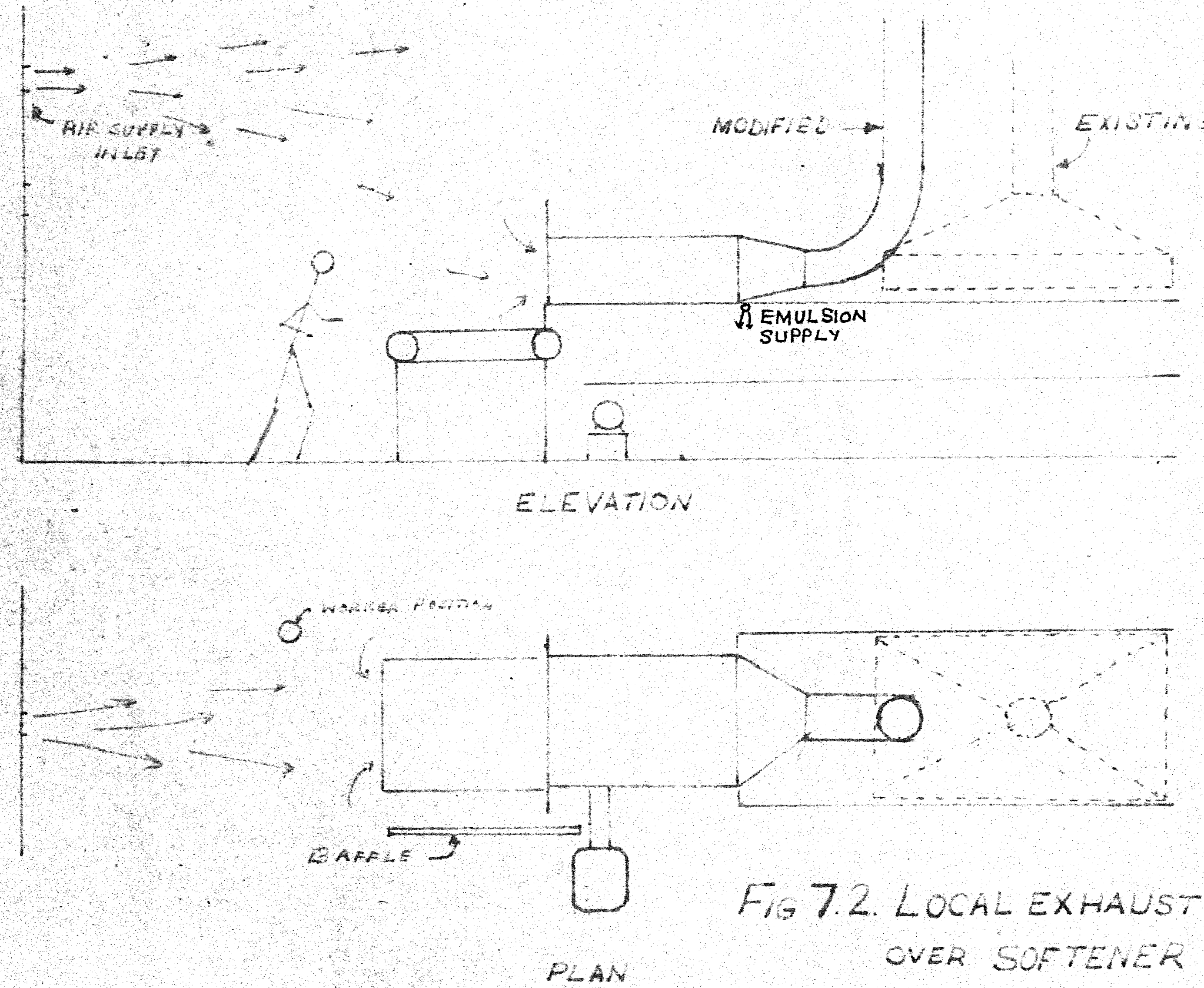


Fig 7.2. LOCAL EXHAUST OVER SOFTENER

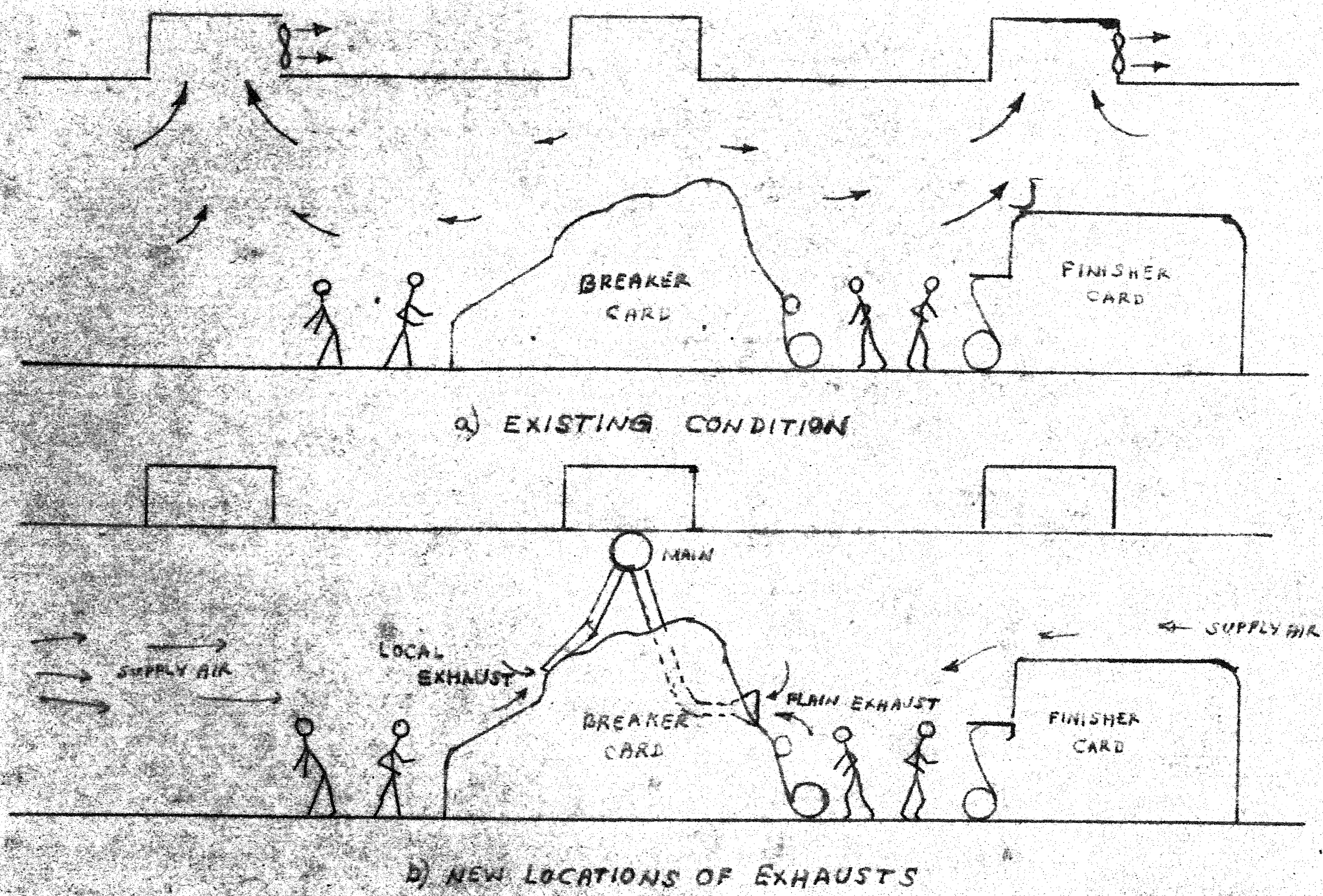


FIG 7.3. EXHAUST SYSTEM CARDING SECTION (JUTE)

required capture velocities at the source. The induced velocities below the exhaust fans are given in Table 7.3.

Table 7.3 Induced velocities below exhaust fans in carding sections (based on theoretical computations).

Distance X (m)	Velocity at X below fans					
	F_1(4.88 m^3/sec.)		F_2(4.50 m^3/sec.)		F_3(1.75 m^3/sec.)	
	cm/sec.	fpm	cm/sec.	fpm	cm/sec.	fpm
0	97.5	191.0	90.0	176.5	35.0	68.5
(0.463)+					(24.5)	(50.0)
1.0	32.5	63.7	30.0	58.8	11.6	22.8
(1.156)			(24.5)	(50.0)		
(1.22)	(24.5)	(50.0)				
2.0	10.7	21.0	10.0	19.6	3.9	7.6
3.0	5.1	10.0	4.7	9.1	1.8	3.6
4.0	2.9	5.8	2.7	5.3	1.1	2.1
5.0	1.9	3.7	1.8	3.4	0.7	1.3

+ Values inside parentheses show critical velocity and the distance from the exhaust fan where this velocity is induced.

A velocity of 50 fpm, required for capturing fine particulates, occurs, only very near the exhaust openings. The room air velocities measured at lower levels below the fan are higher than calculated values indicating that these are not induced by the exhaust fans. _ ventilation system intended

for reducing particulate pollution will be effective only if the velocities induced by the exhaust arrangements at the source are at least 25 percent more than the prevailing velocity there (Hemeon 1963).

4) <u>Locations of air supply inlets:</u>

Air supply points in the carding section are located at heights of about 2.65 m above the floor. The sources are located below this level and the exhausts above it. The effectiveness of the exhausts in mremoving particulates will be reduced by this arrangement.

5) <u>Locations of doors, windows and other openings :</u>

The location of the entrance door D_1 adversely affects the efficiency of the local exhaust over the softening machine. Air velocities near the hood caused by flow through the door ranged from 60 - 140 fpm compared to the face velocity of nearly 80 fpm of the hood. The cross draught produced by the air flow adversely affect the particulate capturing capacity of the exhaust hood.

The difference in height between the centres of inlets and outlets is only 70 cm. and the chimney effect produced by this height is very low. Utilization of natural ventilation, especially, in the less polluted sections will be less effective due to the low chimney effect.

7.1.4 Remedies:

The remedies for the various defects are presented below :

1) <u>Better location of exhaust system in softener section :</u>

The location and orientation of the exhaust hood should preferably be changed as shown in Fig. 7.2. The exhaust hood should be located just ~~after~~ before the emulsion supply point. A cover over the length of softener in front of the hood, will prevent the escape of particulates and will effectively bring the hood face mearer to the worker. Air supply from behind the worker will give a push-pull effect for the total system and particulates escaping while feeding the jute to the machine also will be trapped by the air stream. The design of the modified local exhaust system is given in Appendix - I .

2) <u>Exhaust Arrangements in Carding Section :</u>

To get a desirable flow pattern for preventing the dispersion of particulates into the working environment, the exhausts in this section should be located above the breaker carding machines. Appendix - I gives designs for various alternatives. Exhausts provided on the roof which will give a velocity of 0.245 m/sec (50 fpm) at the source will have a total extraction rate of 152.69 m^3/sec., nine times that for local exhaust system. Lowering of the exhaust

openings upto 1.1 m by piping does not reduce the extraction rate. A system with local exhausts for the Breaker and finishing cards will have the least total extraction rate of 16.92 m^3/sec., But the initial cost in this case will be maximum because of the pipings and enclosures needed. Also, this system will not take care of the particulates leaking out of the enclosures. A combination of local exhaust for the breaker carding machine and a plain exhaust opening for the area between the breaker and finisher cards has a flow rate of 26.93 m^3/sec. The initial cost in this case will be considerably less because of less duct work. Also this will serve better the working area between the carding machines. Particulates leaking out of the enclosures also will be taken care of. The actual choice will have to be made on the basis of particulate removal efficiency and of overall economy. According to present analysis alternative 4 given in Appendix - I . seem to be more desirable in most cases.

3) <u>Air supply inlets :</u>

In the softener and carding sections, air supply in lets should be so located that a push-pull effect is attained. For this, the air supply points should be located along the transverse direction (east-west direction) and the flow should be at right angles to it. The existing air supply inlet in this section should be closed.

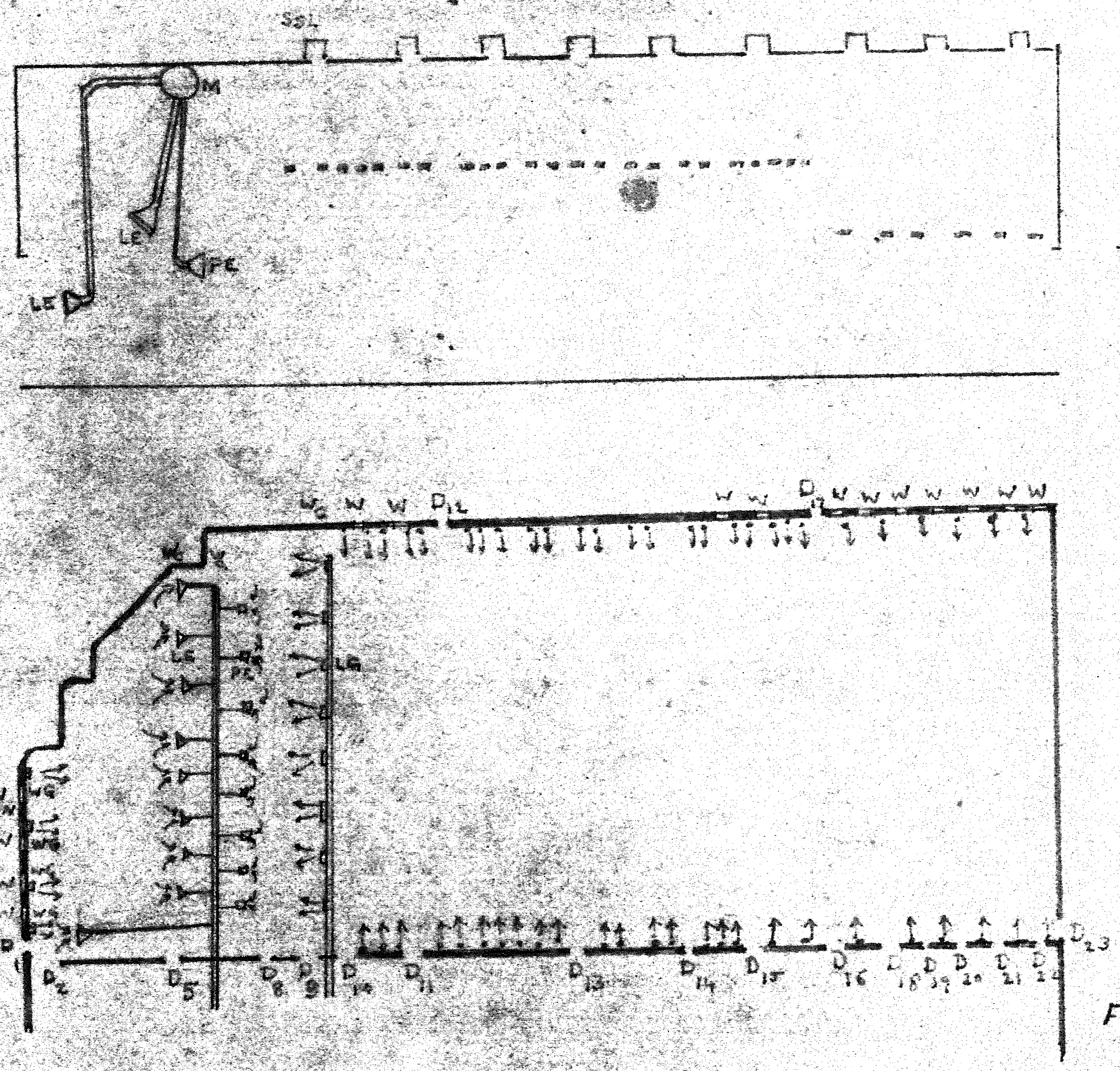
4) Locations of doors, windows and other openings :

In the softener and carding sections, as the ventilation is a forced one, openings other than inlets and outlets should be a minimum. The entrance door D_1 is very essential for the movement of men and materials. The same is the case with doors D_2 and D_5. Doors D_3, D_4, D_6 and D_7 may be closed. To avoid cross draughts produced by air flow through D_1, a baffle which protects the face of the local exhaust hood should be provided.

To increase the chimney effect, the sunlight openings in the drawing, spinning and weaving sections may be modified to serve the dual functions of admitting sunlight and carrying air inwards or outwards. For this, shutters should be provided on the eastern and western sides of these openings.

7.2 MODIFIED VENTILATION SYSTEM IN THE JUTE MILLS

Fig. 7.4 shows the modified ventilation system in the jute mills. Local exhausts are provided over the softener and breaker carding machines. The area between breaker and finisher cards is served by plain exhaust openings. A main running over the breaker cards carries the particulates collected from the section for treatment or discharge into the atmosphere.



SYMBOL	DESCRIPTION	NUMBERS
D_1, D_2, D_5, D_8 to D_{23}	DOORS RETAINED	19
D_3, D_4, D_6, D_7	DOORS CLOSED	4
W_N	NEW WINDOWS	4
W_C	WINDOW CLOSED	3
W	WINDOWS RETAINED	11
SSL	SUNLIGHT OPENINGS WITH SHUTTERS	16
LE	LOCAL EXHUST	9
PE	PLAIN EXHAUST	8
WG	WALL GRILLES	4
LG	NEW LATERAL GRILLES	11
→ & ⇒	AIR SUPPLY INLETS: 52	

FIG 7.4. MODIFIED VENTILATION CONDITIONS [JUTE MILLS]

7.2.1 Operation schedule :

For the new ventilation system, the operation schedule is given in Table 7.3.

Table 7.3 Operation schedule for modified ventilation system in the Jute Mills

Unit	Periods of operation or of keeping open
Local and other exhausts	Throughout the day on all working days
Air supply inlets in the softener section (wall grilles)	Throughout the day on all working days
Air supply inlets on the other side of carding section (Lateral outlet from supply main)	During summer and winter months when the windows will be kept closed
Air supply inlets serving other sections	During summer months
Windows in drawing, spinning and weaving sections(east)	During all periods when outside climate permits their opening
Doors on eastern, northern and southern sides	Throughout the day on all working days (Partially closed during winter months).
Doors on western side	Throughout the year
Shutters in sunlight openings	During all periods when outside climate permits the opening of windows on eastern side.

7.3 VENTILATION CONSIDERATIONS IN THE PLANNING AND DESIGN OF A NEW JUTE MILL

A desirable ventilation system would be one which is economical in the long run and at the same time serves the purpose effectively. Natural ventilation system is always the most economical one. But it is, usually, inadequate to reduce pollution conditions in an industry to permissible levels under all weather conditions. A mechanical ventilation system on which one has complete control will be a better choice for industrial ventilation from the point of industrial hygiene.

In the case of a jute mill the preparing sections are more polluted and a forced ventilation system should be chosen for these sections. From drawing sections onwards, the particulate production is very low and the ventilation system should be designed for the maximum worker comfort. Fig. 7.5 shows the outlines of a ventilation system for a jute mill suggested on the basis of these principles. The softener and carding sections are separated from other sections to ensure better control. The windows and ventilators are so placed that natural ventilation could be made use of whenever possible. The orientation of the building also is planned to meet this purpose. The operation schedule for the new ventilation system is given in Table 7.4.

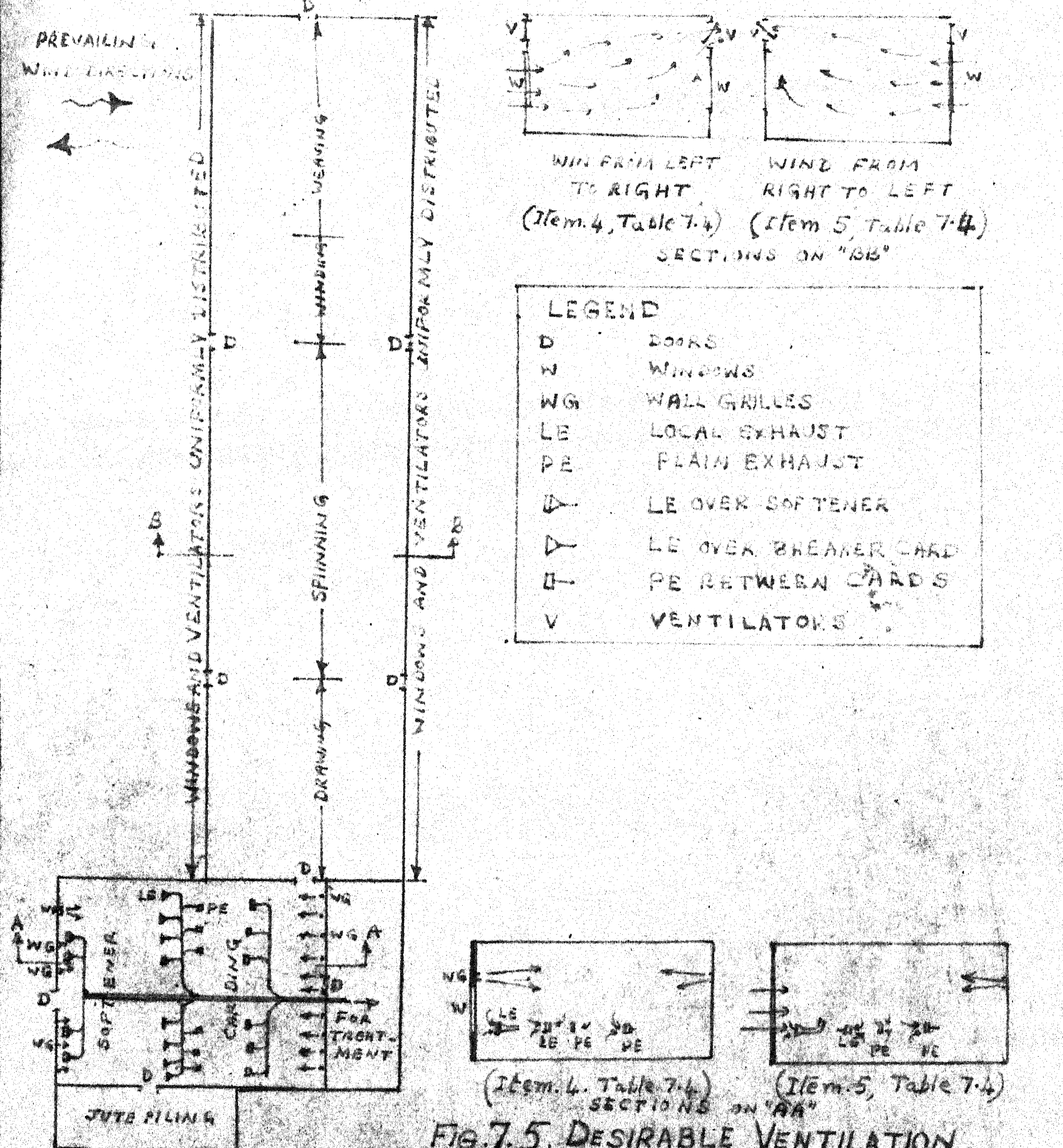


FIG. 7.5. DESIRABLE VENTILATION SYSTEM FOR NEW JUTE MILL

Table 7.4 Operation schedule for new ventilation systems in a Jute Mill

Unit	Period of operation
Local and other exhausts	Throughout the day on all working days
Air inlets on the left side as in Fig. 7.5.	During all the working hours when the windows on the left side could not be opened.
Air inlets on the right side as in Fig. 7.5.	Throughout the day on all working days irrespective of wind direction and temperature difference.
Windows on left side	Depending on the season. Opened when the wind is from left to right. When it is not possible to open the windows due to extreme temperature conditions they should be kept closed
Windows on right side	When the wind is from right to left. Closed when temperature outisde does not permit their opening.
Ventilators on left side	Opened when windows on right side are opened.
Ventilators on right side	Opened when the windows on left side are opened.
Air supply inlets in drawing, spinning and weaving sections	During summer months when cold air is to be supplied for worker comfort. At this time all the windows and ventilators in this section are closed.

CHAPTER VIII

CONCLUSIONS AND SUGGESTIONS

8.1 CONCLUSIONS

From the limited studies carried out the following conclusions could be drawn :

1) Particulate pollution in the preparing sections of fibre factories are rather high and would pose health hazards to the workers.

2) Natural ventilation is inadequate to reduce particulate pollution to the permissible levels in the highly polluted preparing sections of all fibre factories. In the case of jute mills a well planned natural ventilation system will be sufficient for sections following the drawing section and including that if they are separated from the preparing sections.

3) Provision of exhaust fans alone will not reduce particulate pollution to the permissible levels. Maximum efficiency of particulate removal could be expected only if flow patterns with adequate transport velocity are developed around the sources such that particulates will not disperse into the working environment but will be transported to the exhaust openings.

4) The transport of fibre particles in the horizontal direction is more diffcault than that in the vertical direction. This indicates that the exhaust openings for the removal of fibre particulates should be so located that the flow induced, is in the vertical direction.

5) With a well designed ventilation system having proper locations of inlets and outlets and adequate exhaust flow rates, it is possible to reduce particulate pollution to permissible levels in all sections of fibre factories throughout the year.

8.2 ENGINEERING AND HYGIENIC IMPORTANCE OF THE PRESENT STUDY

The main difficulty in implementing industrial hygiene measures in India is the dearth for factual informations regarding pollution conditions in industries. On this score, the present study will be beneficial as it provides some useful data. Some of the significant factors are given below :

1) The rate of production of particulates by various machines and the size distribution of the particulates will provide useful data in planning control measures.

2) It is established that the effective removal of particulates is possible only by creating particular flow patterns having adequate velocity. This will serve as the basis of design for any ventilation system for reducing particulate pollution.

3) Informations regarding particle size distribution, weight fractions of particulates of sizes less than 10 microns, percentage of free silica and presence of microorganisms in the particulates of factory room air are of hygienic significance and may be made use of in the diagnosis and treatment of diseases among fibre factory workers.

8.3 SUGGESTIONS FOR FURTHER STUDIES

Lot more work is needed to be carried out in the fibre factories for ascertaining pollution conditions, its effects on workers and its control. A few possible directions are mentioned below :

1) An elaborate study with sampling and measurements during all the months of an year to give a more clear picture of the seasonal variations in pollution conditions and the influence of natural ventilation . A natural ventilation system designed on the basis of such complete data will be more effective in reducing pollution.

2) The effect of pollution on the health of workers be carried out in collaboration with medical profession.

3) Detailed studies of particulate properties like hygroscopicity, dielectric constant, etc and their influence on the flocculation and transport of the particulates to help in designing better control measures.

4) Determination of velocity distribution inside the factory rooms under various conditions to help in deciding optimal modifications to the existing ventilation conditions and designing better ones. Computer aided-simulation model studies may be carried out for this purpose.

5) Model and pilot-plant studies as also in-plant studies, to verify the applicability of suggested improvements.

6) To study the influence of a particular phenomenon, say, temperature or relative humidity on the production and transport of particulates, we should be capable of keeping all other influencing factors constant and vary the interested phenomenon. But this was not possible because of the particular field conditions. So only the combined effect of influencing factors could be observed. A model study can solve such problems.

7) Ventilation studies could not be carried out in cotton and woollen mills and comparison was possible only on the basis of size-distribution of particulates.

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APPENDIX - I : Designs

1.1 Local exhaust over softener:

Data

Width of source	1.0 m
Distance of worker from source	1.0 - 1.5 m
Transporting velocity	17.85 m/sec (3500 fpm) (Witheridge 1958)

Design

Assume a velocity of 0.245 m/sec (50 fpm) at a distance of 1.0 m from the hood face. Let the face area of hood be $1.0 \times 0.3 = 0.3$ m^2.

Then rate of flow,

$$Q = 0.75\ V(10\ x^2 + A)$$

$$= 0.75 \times 0.245\ (10 \times 1^2 + 0.3)$$

$$= 1.892\ m^3/sec.$$

Face velocity $V_o = \frac{1.892}{0.3} = 6.32$ m/sec.

$= 1240$ fpm.

Area of transporting pipe

$$\frac{1.892}{17.85} = 0.106\ m^2$$

Dia of pipe = 36.75 cm

Velocity distribution

X	V	
(m)	m/sec	fpm
0.5	0.865	170
1.0	0.245	50
1.5	0.1105	21
2.0	0.0623	12

1.2 Ceiling exhaust in carding :

Distance of source = 2.69 - 4.53 on feeding side

Distance of the centre of breathing zone = 3.94 - 5.25 on receiving side

Let the velocity of flow at 4.53 m be 0.245 m/sec (50 fpm)

$$Q = 0.75\ V\ (10\ X^2 + A_f)$$

neglecting A_f,

$$Q = 0.75 \times 0.245 \times 10 \times (4.53)^2$$

$$= 37.7\ m^3/sec.$$

$$A_f = \frac{37.7}{20.4} = 2.11\ m^2$$

Section = 145 x 145 cm^2

When the exhaust is lowered by 1.0 m.

Distance of source = 1.8 - 3.94 m from exhaust

Distance of breathing zone = 3.2 - 4.75 m on receiving side.

Rate of flow for plain exhaust is given by

$$Q = V(10\ X^2 + A_f)$$

$$= 0.245\ (10 \times 3.99^2)$$

$$= 41.7\ m^3/sec.$$

Lowering the exhaust face does not reduce flow rate.

I-3 <u>Local exhaust over carding machines</u> (entry point)

Length of source = 2.0 m

Let the capture velocity at a distance of 50 cm from the exhaust be P 0.245 m/sec. (50 fpm)

The flow rate for a slot flanked by a surface is given by

$$Q = 2.8\ LVX$$

$$= 2.8 \times 2.0 \times 0.245 \times 0.5$$

$$= 0.68\ m^3/sec.$$

Face velocity = 0.68/2.0 x 0.1 (assuming slot face dimension as 2 x 0.1 m)

= 3.4 m/sec (666 fpm).

Area of transporting pipe $= 0.68/17.85 = 0.038\ m^2$

Choose 22 cm φ pipe.

Velocity distribution.

	V	
X = (m)	m/sec	fpm
0.1	1.213	238
0.2	0.607	118
0.3	0.405	79
0.4	0.304	60
0.5	0.243	48
1.0	0.121	24

I-4 <u>Local exhaust for carding for hopper below machine :</u>

Pipe dia recommended = 9'' = 22.86 cm (area = 0.041 m^3 (Alden 1948)

Static suction in inches of water = 0.75''

Velocity of flow $= 4005\sqrt{0.75}$

$= 3500$ fpm

$= 17.85$ m/sec.

Rate of flow $= 0.041 \times 17.85$

$= 0.732\ m^3/sec.$

I-5 <u>Local exhaust for finisher card</u> (Alden 1948)

Pipe dia recommended = 6''

area $= 0.01825\ m^2$

Static suction	=	1'' (Water gauge)
Velocity of flow	=	$4005 \sqrt{1}$
	=	4005 fpm
	=	20.4 m/sec.
Rate of flow	=	0.01825 x 20.4
		$0.373 \ m^3/sec.$

I-6 <u>Plain exhaust between carding machines :</u>

Location 1.75 m above floor level. Let the velocity of flow at 1 m be 0.245 m/sec. (50 fpm)

$$Q = V(10\,X^2 + A_f)$$
$$= 0.245(10 \times 1^2)$$
$$= 2.45 \ m^3/sec.$$

Assume a size of $60 \times 30 \ cm^2$

$$\text{Area} = 0.18 \ m^2$$

$$\text{Face velocity} = \frac{2.45}{0.18} = 13.6 \ m/sec.$$
$$= (2665 \text{ fpm})$$

$$\text{Area of transporting pipe} = \frac{2.45}{17.85} = 0.137 \ m^2$$

Choose 41.8 cm φ pipe.

Velocity distribution using formula $Q = V(10\,X^2 + A_f)$

X(m)	V m/sec.	V fpm
0.5	0.95	186
1.0	0.24	48
1.5	0.11	20
2.0	0.06	12

I-7 Possible Combinations :

Item	System	Flow rate (m^3/sec)	Remarks
1.	Exhausts at ceiling 4 numbers	37.7 x 4 = 150.8	Piping and initial cost least. Recurring cost too much.
2.	Exhausts with opening lowered(4 numbers)	41.7 x 4 = 166.8	Short length of piping, initial cost low, Recurring cost high.
3.	Local exhausts system for all machines	1.892x1=1.892 0.680x8=5.440 0.732x8=5.856 0.373 x 10 =3.730 Total 16.918	Initial cost maximum Maximum length of piping. Particulates leaking out is not removed.
4.	Local exhaust system for softeners and entry points of breaker cards. Plain exhausts for area between carding machines.	1.89x1= 1.89 0.68x8= 5.44 2.45x8=19.60 Total 26.93	Initial cost medium length of piping medium. Particulates from the breathing zone are removed.

The actual choice will have to be made on the basis of particulate removal efficiency and of overall economy. According to the present analysis alternative 4 would seem to be more desirable in most cases.

I-8 <u>Air supply inlets :</u>

The design of air supply system for item No. 4 above is given below. From the measurement of the existing air distribution system the value of K in the equation

$$U_{cl} = \frac{K\sqrt{A_o}U_o}{X}$$

was found to be 1.77. This agrees with reported values of K for grilles. The design is done to give a centre-line velocity of 0.245 m/sec. (50 fpm) at a distance where the air stream reaches the workers.

$$X = 18.8 \text{ m}$$
$$U_{cl} = 0.245 \text{ m/sec.}$$

Total discharge should be sufficient to make-up the air extracted.

Total discharge from the left side = 1.892 + 0.68 x 8
= 7.332 m^3/sec.

Let there be 4 inlets

Discharge per inlet = 1.833 m^3/sec.

i.e., $A_oU_o = 1.833$, where A_o is the face area of inlet.

$$U_{cl} = \frac{K\sqrt{A_o}U_o}{X}$$

Substituting for U_{cl}, $\dot{K}$, X and A_oU_o,

$$U_o = 2.89 \text{ m/sec (566 fpm)}$$

$$A_o = \frac{1.833}{2.890} = 0.634 \text{ m}^2$$

Choosing an opening of 1.25 x 0.5 m with area 0.625 m^2, the face velocity = 2.93 m/sec (575 fpm)

Air supply from right side = 19.6 m^3/sec.

No. of inlets required $= \frac{19.6}{1.833} = 10.7$

Provide 11 inlets of size 1.25 x 0.5 m with face velocity 575 fpm.

I-9 Duct system design :

The velocity pressure method outlined in the 'Duct Design Procedure' (American Conference of Governmental Industrial Hygienists 1964) was used for the duct-system design. The design includes the following steps :

1) Preparation of lay-out of the duct work.
2) Design of hoods
3) Determination of air flow rates for each exhaust hood.
4) Assuming air velocities (3500 fpm) for each duct, determination nearest duct diameter. Choosing available diameter of pipe (ACGIH 1964, p. 6 - 1).

5) Determination of entrance loss for each hood using tables (ACGIH 1964, Fig. 6.5 p.6.14).

6) Determination of duct friction (ACGIH 1964, Fig. 6.16, p.6.26 and Fig. 6.20, p.6.32).

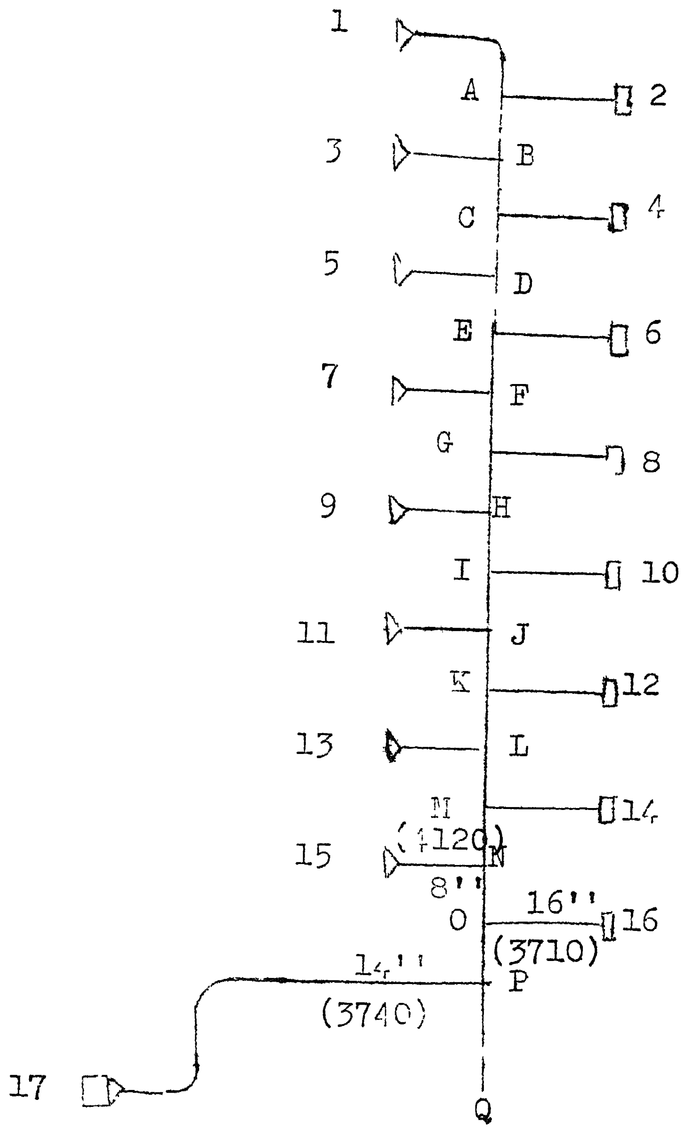
7) Balance pressure drop by adjusting duct size. For this the total pressure drop from any point in the system to each upstream opening was made same.

8) Summarization of system resistance.

9) Selection of appropriate and adequare fan. Steps 8 and 9 were not done in the present design as the portion designed was only part of a bigger system , complete details of which were unknown.

I.9.1 Design of hoods :

Hood Name	Type	Area m^2	m^3/sec.
Local exhaust hood over sof-tener	Flanged with cover in front	0.30	1.892
Local exhaust over breaker card	Slot	0.20	0.680
Exhaust bet-ween carding machines	Plain	0.18	2.450



Local Exhaust over softener

Local exhaust over Breaker card

Plain Exhaust between carding machines

Fig. I-1 LAY-OUT OF DUCT WORK

I.9.2 Duct System Design

Name	Straight Length (ft)	Elbows (No.-angle) degree	Entries (No.-angle) degree	cfm	Duct dia. (inches)	Corrected dia (inches)
A1	7.40	$1 - 90^{o}$		1440	8	8
A2	8.20	$1 - 90^{o}$	$1 - 30^{o}$	5180	16	15
AB	5.74			6620	18	
B3	4.92		$1 - 30^{o}$	1440	8	8
BC	5.74			8060	20	
C4	8.20	$1 - 90^{o}$	$1 - 30^{o}$	5180	16	15
CD	5.74			13240	26	
D5	4.92		$1 - 30^{o}$	1440	8	8
DE	5.74			14680	28	
E6	8.20	$1 - 90^{o}$	$1 - 30^{o}$	5180	16	15
EF	5.74			19860	32	
F7	4.92		$1 - 30^{o}$	1440	8	8
FG	5.74			21300	34	
G8	8.20	$1 - 90^{o}$	$1 - 30^{o}$	5180	16	14.5
GH	5.74			26480	38	
H9	4.92		$1 - 30^{o}$	1440	8	7.5
HI	5.74			27920	38	
I10	8.20	$1 - 90^{o}$	$1 - 30^{o}$	5180	16	14.5
IJ	5.74			33100	42	
J11	4.92		$1 - 30^{o}$	1440	8	7.5
JK	5.74			34540	42	
K12	8.20	$1 - 90^{o}$	$1 - 30^{o}$	5180	16	14.5
KL	5.74			39720	46	
L13	4.92		$1 - 30^{o}$	1440	8	7.5
LM	5.74			41160	46	
M14	8.20	$1 - 90^{o}$	$1 - 30^{o}$	5180	16	14.5
MN	5.74			46340	50	
N15	4.92		$1 - 30^{o}$	1440	8	7.5
NO	5.74			47780	50	
O16	8.20	$1 - 90^{o}$	$1 - 30^{o}$	5180	16	14.5
OP	5.74			52960	52	
P17	57.35	$2 - 90^{o}$		4000	14	14.5
PQ	Not fixed			56960	54	

(२) लुप्तविसर्ग, उपहतविसर्ग तथा (३) व्रीडा, घृणा, अमंगल-व्यंजक तीन भाँति, विसंधि ये पाँच दोष संस्कृत ही में है।

४. हतछंदस

रसविरुद्ध छंद, होय कै लक्षण-हीन 'सो हतवृत्त' द्वै भाँति है।

(१ रसविरुद्ध छंद) यथा—

"बैनी उलट्टि परी कुच उप्पर चंपक-माल लगी लथ पथ्थिय।
कनक-जँजीर सुंड गहि झुम्मत मनहु मत्त मनमथ्थको हथ्थिय॥"

यह शृङ्गाररस-विरुद्ध छंद है। भरतोक्त छंदोविभाग तैं तत्तन्नायक रसोपयुक्त छन्द जानिये।

(२ लक्षण-हीन छंद) यथा—

"हाथ तें चौसर छूटि पर्यो तहँ 'ब्रह्म' भनै उपमा यह जोई।
मनौ रस राहु निकास लियो ससि डारि दियो छिति में करि छोई॥"

इहाँ भगणात्मक सवैया की चौथी तुक में एक लघु अधिक है। यद्यपि लघु अन्यत्र होत हैं कहूँ, चौथे पद में नीको नाहिं लगतु।

"आपने आनन-चंद की चाँदनी सों पहिले तन-ताप बुझायो॥"

इहाँ यतिभंग है।

५. न्यूनपद, यथा—

"कोकिल कूकनि हूक उठै 'मुरलीधर' मोर मरूरनि मारी।"

इहाँ "मोर-सोर सुनै मरूरनि मारी" इतनो 'न्यूनपद' है।

६. अधिक पद, यथा—

"काम जित्यौ जग कामिनी-नैनकमल लहि बान॥"

इहाँ "कमल" अधिक पद है।